NICOLET SCIENTIFIC CORPORATION

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Serial Number 7048006

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Instruction Manual

for

MODEL 444

MINI-UBIQUITOUS®

FFT COMPUTING SPECTRUM ANALYZER

OFFICIAL RECORDS STATION
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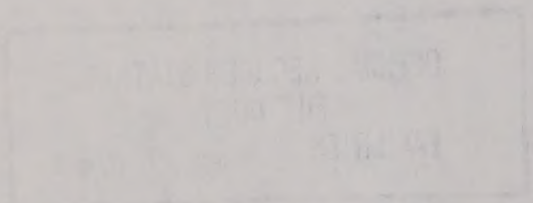

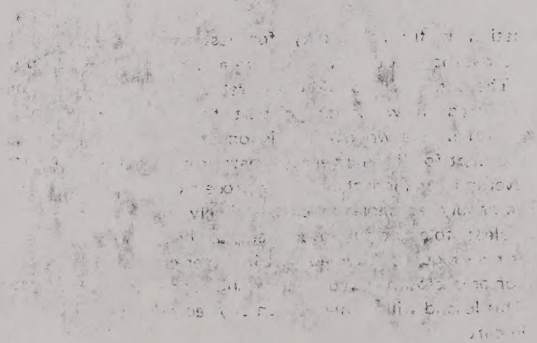

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I would like to thank you personally for having selected Nicolet Scientific Corporation equipment for your application. Most instruments that we produce are burned-in and subjected to vibration and temperature tests before shipment, to maximize the equipment's reliability.

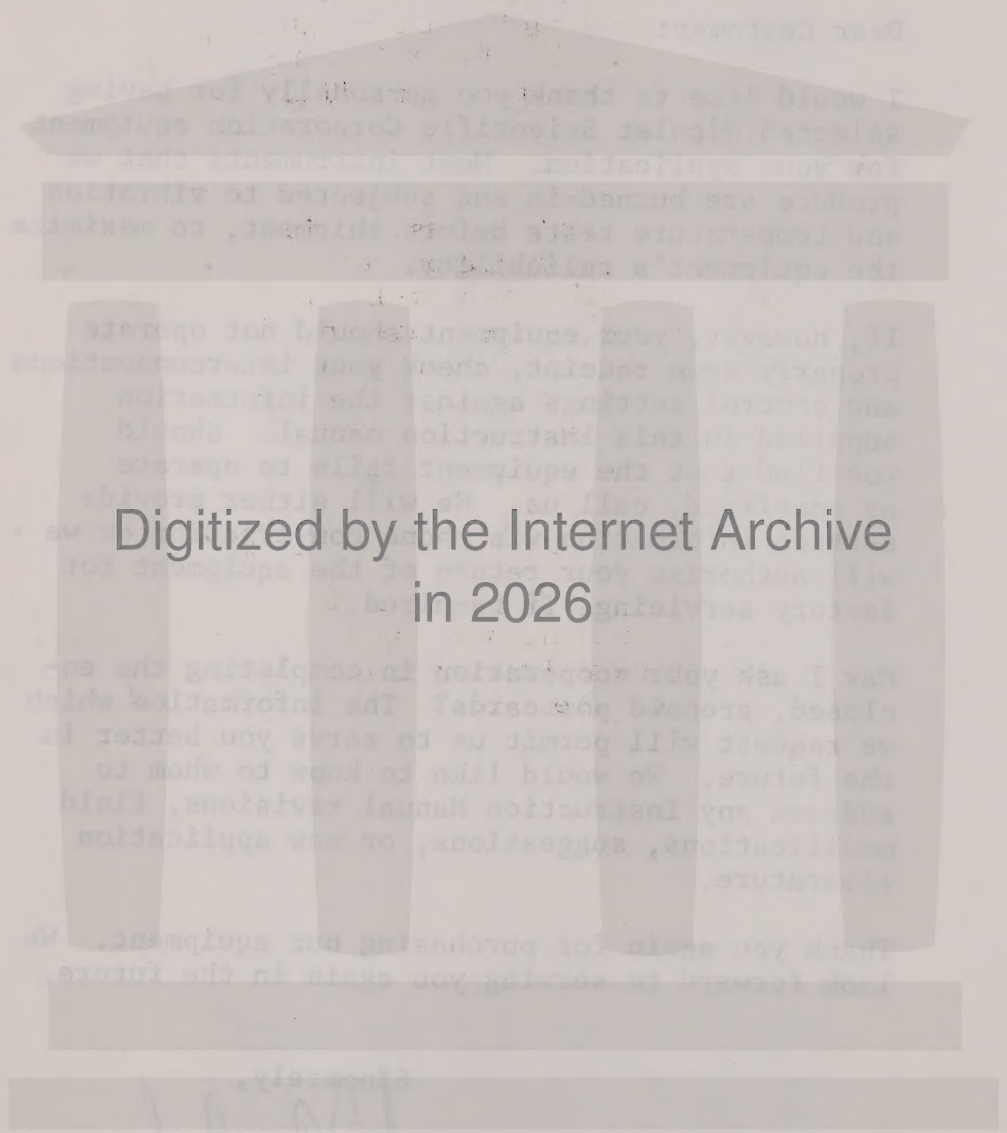
If, however, your equipment should not operate properly upon receipt, check your interconnections and control settings against the information supplied in this instruction manual. Should you find that the equipment fails to operate as specified, call us. We will either provide service information via phone conversation or we will authorize your return of the equipment for factory servicing, if required.

May I ask your cooperation in completing the enclosed, prepaid postcards? The information which we request will permit us to serve you better in the future. We would like to know to whom to address any Instruction Manual revisions, field modifications, suggestions, or new application literature.

Thank you again for purchasing our equipment. We look forward to serving you again in the future.

Sincerely,

Henry J. Bickel
President



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INSTRUCTION MANUAL NOTICE

Every effort has been made by the Engineering and Service Departments of Nicolet Scientific Corporation to present accurate, helpful, and readily understood instructions in this manual. Our goal is to assist you in the efficient operation and maintenance of your precision instrument. The following information will facilitate your use of this publication.

CORRECTIONS:

Sometimes, changes in text or descriptions of circuit design changes cannot be incorporated in the printed manual (and its schematic diagrams). In this event, we provide you with the latest data on the colored pages in this manual following this page. These colored pages cover corrections to the text or to certain of the schematic diagrams, and must be read for the manual to properly reflect the equipment you received.

DATA COVERING OPTIONAL FEATURES AND SYSTEM CONFIGURATIONS:

Data covering certain optional features of our equipment, or special system configurations are provided in the text. If you have not ordered these options, the corresponding section of the manual does not apply to the equipment you received.

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SPECIAL INSTRUCTIONS

WARNING

CONCERNING SAFE OPERATION OF ELECTRICAL EQUIPMENT:

1. This equipment is supplied with a detachable, rubber-covered electrical ac power line cord. One termination of the cord is a standard three-contact female connector for mating the AC INPUT receptacle on the instrument's rear panel. The other termination is a 3-prong male connector for mating a power source outlet, with one of the power source terminals at ground potential. THIS EQUIPMENT SHOULD NEVER BE OPERATED UNLESS IT IS PROPERLY GROUNDED.

2. If you use a 2-prong to 3-prong adapter for mating to your power source outlet, make sure that the pigtail lead (the grounding strap which is provided on the 2-prong adapter) is securely grounded. FAILURE TO FOLLOW THIS WARNING MAY RESULT IN ELECTRICAL SHOCK TO OPERATING AND MAINTENANCE PERSONNEL.

3. Nominal 115-volt or 220-volt ac potentials are present on the terminals of the front panel POWER switch and on the rear panel ac POWER INPUT connector and line protective fuse. Nominal 115-volt or 220-volt ac potentials also exist on the terminal strip of the self-contained power supply module and at various electrical terminals within the power supply module. ALWAYS EXERCISE EXTREME CARE WHEN WORKING IN OR NEAR THESE AREAS TO AVOID SEVERE ELECTRICAL SHOCK!

4. Lethal dc voltages are present within all Nicolet Scientific Corp. manufactured equipment utilizing switching type power supplies and CRT displays. This equipment should only be serviced by TRAINED PERSONNEL using extreme care to avoid severe electrical shock.

SPECIAL INSTRUCTIONS

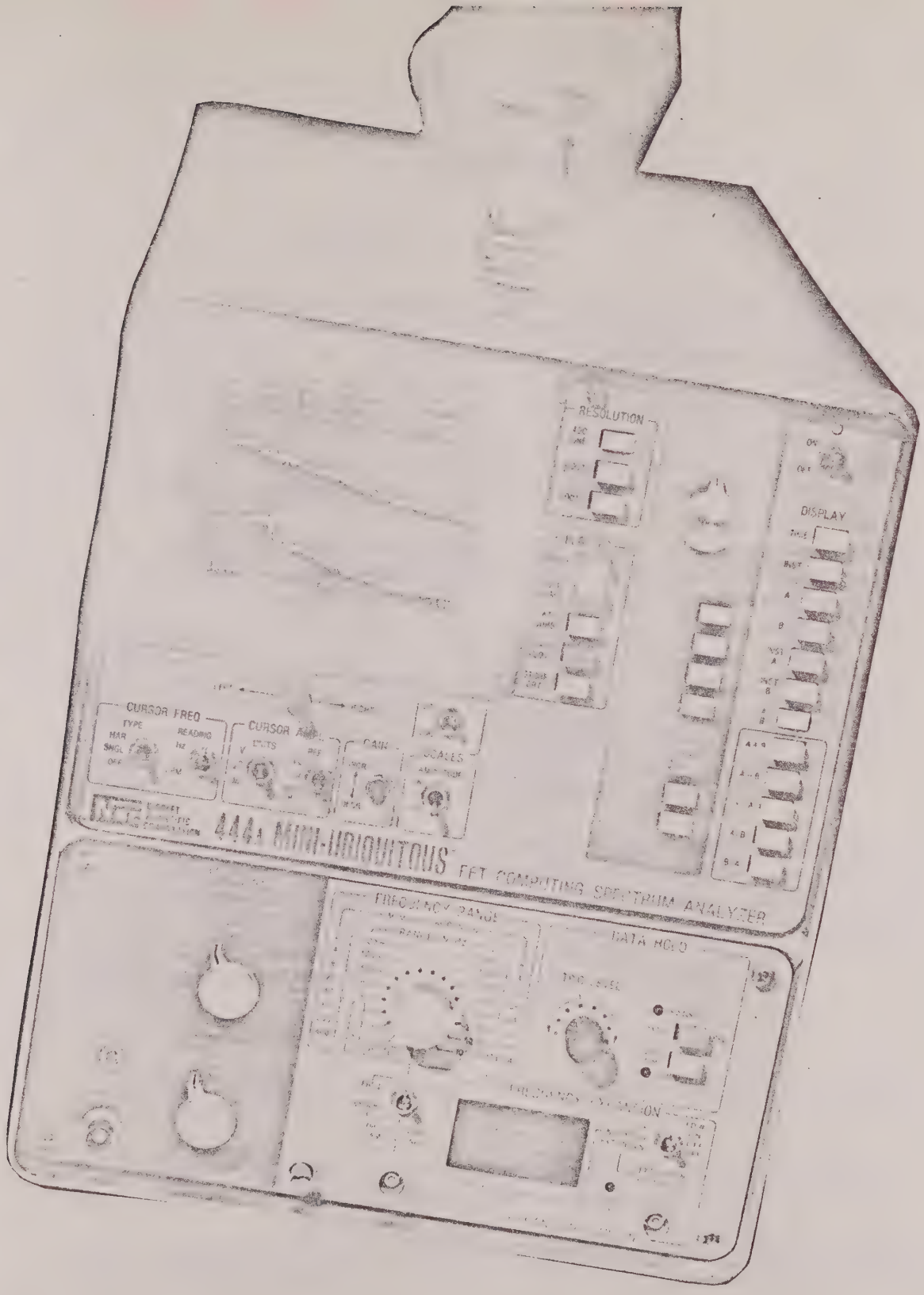


FIGURE 1-1. MODEL 444 MINI-UBIQUITOUS®
SPECTRUM ANALYZER

SECTION I

INTRODUCTION

1-1. Scope of Manual

This manual covers the description, specifications, and operation, as well as the block diagram description of the MINI-UBIQUITOUS® 444 portable, Real Time Spectrum Analyzer. Also included is a review section useful to the operator. This section describes how to obtain meaningful information from the display by use of the cursor and calibration constant. Setup information for calibration in terms of input voltage, engineering units, and power spectral density are also provided.

The 444 combines the precision of all digital computation of a 400 line spectrum with the usefulness of an internally generated graticule on a built-in display and annotation on the display of all significant front panel settings. See Figure 1-1. The 444 also features sixteen frequency analysis ranges, transient capture mode, linear or logarithmic readout of horizontal and vertical axes, a vertical cursor for the readout of any single frequency element and its corresponding spectral value, uniform or Hanning weighting window, display of input time signal stored in the input buffer, and external sampling input.

The 444 contains a dual memory averager which can average up to 512 spectra in sum, difference, exponential or peak mode. The computational capability of the 444 permits addition, subtraction and ratio of the averager memory contents as well as direct visual comparison on a dual display. 1/3 and 1/1 octave display of averaged data is available as an option.

1-2. Organization of Manual

A. SECTION II covers the detailed specifications of the instrument.

B. SECTION III describes settings and operation of front and rear panel controls and indicators.

C. SECTION IV includes a checkout procedure using the internal TEST signal.

D. SECTION V describes aids to understanding and efficient utilization of the Model 444.

E. SECTION VI presents a description of the Model 444 system block diagram.

F. SECTION VII describes the user adjustments of the Model 444.

G. SECTION VIII describes the optional Expansion Plug-in.

H. SECTION IX covers the warranty applicable to the Model 444. Included are instructions for reshipment of the instrument to the factory, if the equipment is damaged in shipment, or malfunctions after receipt by the user.

I. SECTION X includes a set of schematic diagrams for this instrument, and is the concluding section of this manual.

SECTION II

SPECIFICATIONS

2-1. Display (on Built-in CRT)

A. Data: Repetitive readout of one of the following:

1. Time function, continuous or captured
2. Instantaneous spectrum of time functions
3. Averaged power spectrum A or B
4. Instantaneous spectrum and averaged power spectrum A (dual display)
5. Instantaneous spectrum and averaged power spectrum B (dual display)
6. Averaged power spectrum A and averaged power spectrum B (dual display)
7. Averaged power spectrum A plus averaged power spectrum B
8. Averaged power spectrum A minus averaged spectrum B, or B minus A
9. Averaged power spectrum A divided by averaged power spectrum B, or B divided by A

B. Electronic Graticule

Non-parallax rectangular graticule is generated; 10 marks on frequency axis for linear and 2 marks for log (at 1 and 2 decades below full scale); for single displays, 10 marks on amplitude axis for linear and 6 marks for log (at 10 dB intervals); for dual displays, twice as many amplitude marks are produced; for time, 8 marks for horizontal and ± 5 marks around zero center for vertical, top and bottom correspond to input amplitude full scale; rear panel switch removes graticule.

C. Annotation

For frequency displays, letters and numbers indicate input sensitivity in VRMS, frequency range, type of data, averaging mode, number of spectra averaged, data weighting, display

gain/attenuation, A-weighting on/off, mathematical calculation between averages, and 4-digit I.D. number; for time displays, full-scale input amplitude read as volts (zero to peak); horizontal time scale indicated by "SEC" and frequency scale by "HZ"; indicates origin frequency of expanded range in place of ID number (for 444-26 units) when in expanded mode; rear panel switch removes annotation.

D. Overall RMS Level

Shown on CRT for single spectrum displays (when cursor is on) for 400-line or 1/3 or 1/1-octave (-03 option).

E. Measurement Cursor

Cursor line moved left or right continuously or by single resolution element; intensified dot where line intersects spectrum (if intersection is within graticule); can be turned off.

F. Amplitude at Cursor

Referenced to 1 VRMS and read in units of V, V^2, or dB with respect to 1V (dBV); or read in engineering units directly by reference to any voltage from 1.00×10^{-9} to 999×10^{9} set by front panel GAIN controls; for dual spectra displays amplitudes of each and their ratio at cursor location.

G. Frequency at Cursor

For 400-line spectra, frequency reads in Hz (cycles/sec) or CPM (cycles/minute); also reads 1/3-octave band number if within bands 8 to 49 approximately 6 Hz to 94 kHz (-03 option not required); in ORDERS (external sampling), reads % FS; reads in annotation only when cursor is on.

H. Harmonic Marks

Additional intensified dots illuminate multiples of cursor setting on 400-line spectra; number of dots indicate harmonic number up to a maximum of 5 dots.

I. Display Scales

Lin or log, frequency or amplitude of spectrum

J. Display Gain

Linear - gain of 512 ("X512") to attenuation of 512 ("/512") in binary steps; log - gain of +50 dB to attenuation of -50 dB in 10 dB steps; set by front panel GAIN control.

2-2. Analysis Characteristics (400-line)

A. Frequency Ranges

1, 2, 5, 10, 20, 50, 100, 200, 500, 1,000, 2,000, 5,000, 10,000, 20,000, 50,000 and 100,000 Hz with built-in anti-aliasing filters (1, 2, 5 Hz ranges filtered with 10 Hz filter).

B. Number of Resolution Elements

400 per spectrum (generated from 1024 input time samples); nominal bandwidth, β, is 1/400 frequency range; noise bandwidth is 1.5β (1.0β when data automatically captured or armed).

C. Amplitude Linearity

$\pm$0.1 dB or $\pm$.05% of FS to 66 dB below FS, whichever is greater.

D. Frequency Accuracy and Stability

.01 percent of full scale without warmup.

E. Minimum Detectable Signal

-70 dB typical, -75 dB with background subtraction.

F. Two-Tone Dynamic Range: Typically better than 66 dB.

G. Intermodulation Distortion: -70 dB typical.

H. Amplitude Measurement Stability

$\pm$.1 dB from 10° C to 50° C (50° F to 120° F).

I. Expansion Plug-In (Option -26)

Built-in translator provides one analyzer band of 10 Hz, 50 Hz, 100 Hz, 500 Hz, 1 kHz, 2 kHz, 10 kHz or 20 kHz wide positioned in 10 Hz steps to 100 kHz; extra plug-in cards provide additional ranges (except for 10 Hz which requires modification of basic unit); origin frequency indicated on display (in place of I.D. number).

2-3. Transient Data

A. Data Hold

Manual HOLD/REL button holds data in input memory or allows new data to enter; AUTO ARM (or remote signal) allows next signal over preset level to automatically actuate hold; in auto-hold, 1/8 of memory period before trigger can be viewed; polarity and amplitude of auto-hold triggering selected as $\pm$1/16, $\pm$1/8, $\pm$1/4, or $\pm$1/2 of full input amplitude, lights indicate data being held or unit is armed; one spectrum of held data can be transferred to averager A memory by pushing START A after capture.

B. Viewing Held Data

Time signal can be displayed and plotted; in automatic hold, trigger level indicated by brightened dot on CRT. (Time not displayed when in 1/3 octave or 1/1 octave mode with Option -03.)

C. Data Weighting

Weighting removed automatically in ARMED or when data captured (in AUTO position of rear panel switch), or can be manually controlled using rear panel switch.

D. Memory Period

Length of data stored in the input memory in seconds is 400/frequency range (Hz).

E. Automatic Transient Averaging

Rear panel jumper provides automatic arm, capture and averaging of a succession of input transients (not valid for 1/3 or 1/1-octave mode with Option -03).

2-4. Input Characteristics

A. Input Impedance: 100 kilohms

B. Input Coupling: AC (-3 dB at less than 0.5 Hz), DC

C. Test Signal

Sinewave at 64 percent of display, replacing input signal.

D. Input Amplitude Sensitivity

(Volts RMS Full Scale) 100 MV (-20 dB), 200 MV, 500MV, 1V (0 dB), 2V, 5V, and 10V (+20 dB). Maximum input DC plus AC component = ±50V referenced to ground.

E. Input Amplitude Monitor

Lights indicate peak signal levels - OVERLOAD, -6 dB (greater than 1/2 full scale), -12 dB (between 1/4 and 1/2 FS), -18 dB (between 1/8 and 1/4 FS), and -24 dB (between 1/16 and 1/8 FS); all lights below the signal level illuminated (in OVERLOAD, all lights are on).

F. Input Sampling

12-bit A/D conversion at 2.56 times maximum frequency of range selected on internal sampling (FREQ); external sampling input (ORDERS) sets frequency coverage at 1/2.56 of sampling rate. (Display in orders of rotation requires 2.56 pulses/revolution/order.)

G. Input Filters

Lowpass anti-aliasing filters matched to each range with an initial rolloff of 120 dB/octave (7-pole elliptic); 10-Hz filter on 1, 2 and 5 Hz ranges; frequency response ±0.5 dB (except ±1.0 dB on 100 kHz range).

H. Digital Input

External digital data can be loaded in 2's complement form directly into memory (through rear connector).

I. A-Weighting

Synthesized A-weighting can be applied to ranges of 5K and above for 400-line analysis, or any 1/3 and 1/1-octave ranges (with Option -03).

2-5. Averaging

A. Modes

SUM - power spectra are added (true power averaging)

DIFF - power spectra are subtracted linearly from the previous average (negative amplitudes clipped at display bottom but retained in memory).

EXPON - average changes in time as the signal spectrum changes (N sets exponential time constant); operation equivalent to a "leaking integrator".

PEAK - stores maximum spectrum amplitude at each frequency location during an averaging cycle, producing a profile of maxima.

B. Averaging Control

STOP A - manual stop of averaging in A memory

START A - resets number of measurements count, erases A averager memory (unless in DIFF mode), and starts averaging in A memory.

CONT (Continue) A - starts averaging a A memory without erase; in SUM, DIFF, or PEAK mode, if actual number of spectra averaged is equal to or greater than setting of N, resets count.

TRANSFER A→B - transfers the contents of memory A to memory B, either during averaging in A memory or after averaging has stopped. (400-line, or 1/3-octave with Option -03).

C. Number of Averager Memories

Two for 400-line spectra (plus two for 1/3-octave spectra with Option -03; 1/1-octave display derived from 1/3 octaves).

D. Number of Spectra Averaged - N

Determines time of averaging or time constant of exponential averaging; set from 1 to 512 in binary steps; in CONT, averaging continues until STOP button is pushed.

E. IN-PROCESS Light

Flashes to indicate averaging is taking place; flashes in EXPON until N is reached, then is lit continuously.

2-6. 1/3 or 1/1-OCTAVE ANALYSIS (Option -03)

Range Setting	Center Freq. Range (Hz)	(ANSI Std. 1/3-octave band numbers)	Time Per Anal. (sec)
1/3-oct.			
5k	6.3 - 5,000	(Band 8 - 37)	2.4
10k	12.5 - 10,000	(Band 11 - 40)	1.2
20k	25 - 20,000	(Band 14 - 43) Type E	.8
50k	50 - 40,000	(Band 17 - 46)	.8
100k	100 - 80,000	(Band 20 - 49)	.8
1/1-oct.			
5k	8.0 - 4,000	(Band 9 - 36)	2.4
10k	16.0 - 8,000	(Band 12 - 39)	1.2
20k	31.5 - 16,000	(Band 15 - 42) Type E	.8
50k	63 - 31,500	(Band 18 - 45)	.8
100k	125 - 63,000	(Band 21 - 48)	.8

A. Characteristics

1/3-octaves synthesized from narrow-band spectra; center frequencies, bandwidths, and effective rolloffs meet ANSI Class III standards; 1/1-octaves synthesized from 1/3-octave spectra.

B. Cursor Reading

Center frequency in Hz, 1/3-octave band number and amplitude; ratio at cursor in dual displays.

C. Dual Memories

Two additional averager memories store 1/3-octave spectra.

2-7. Output Characteristics

A. CRT Outputs

X, Y, Z outputs for external annotated display.

B. X-Y Plotting (without interruption of display)

X, Y and pen lift outputs for analog X-Y plotter; plots single spectrum or time function; ORIGIN (zero volts) and FULL SCALE buttons position pen at lower left and upper right of scale; for 400-line log frequency, ORIGIN is first resolution element; in AT CURS, X and Y outputs follow cursor horizontal and vertical position; during PLOT, cursor follows pen while full display is simultaneously produced on CRT; can plot averaged spectra in B memory while averaging is taking place in A.

C. Store CRT

Slows display to match storage oscilloscope (e.g., Tek 613); output for annotated plots using a Tek 4662 digital plotter or annotated display on a Tek 4000 series CRT terminals (required Option -07 RS232 interface); internal control selects one of the following when STORE CRT button is pushed: (1) start paper tape read, (2) output ASCII data for paper tape punch (control settings and amplitude spectrum or time, control settings and real/imaginary and spectrum or time), (3) output ASCII on RS232 (requires Option -07). Internal control also permits operation with Model 144 Digital Tape.

D. Digital Input/Output

16-bit parallel with 4-bit ID code.

E. Remote Control and Sense

Can sense all front panel switches and amplitude lights; can control all front panel switches; 8-bit parallel ASCII output (requires Option -07 HP for HP9800 series calculators, or Option -07 for RS232 ASCII interface).

2-8. Miscellaneous

A. Weight

19 kgm (42 pounds) nominal with typical plug-in.

B. Power

90 - 130 volts or 180 - 260 volts, 48 - 66 Hz, nominal 150 watts.

C. Size

32.6 cm (12-7/8 inches) high including feet and handle, 25.3 cm (10 inches) wide, 51.9 cm (20-7/16 inches) long including maximum front and rear protrusions.

D. Storage Temperature

-55°C to +85°C (-67°F to +185°F)

E. Operating Temperature

0°C to 55°C (+32°F to +130°F)

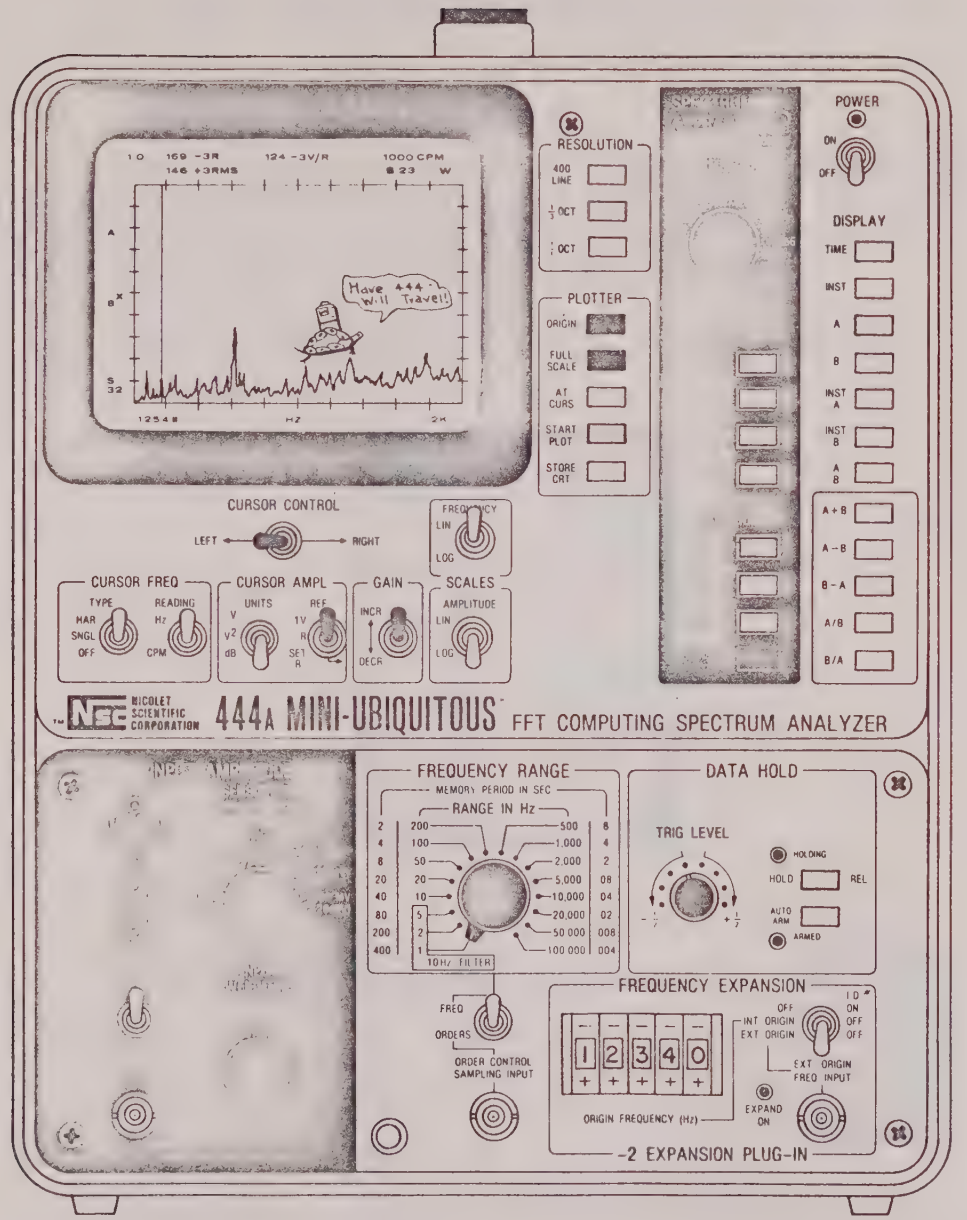


FIGURE 3-1. MODEL 444 MINI-UBIQUITOUS®
SPECTRUM ANALYZER, FRONT PANEL VIEW

SECTION III

FRONT AND REAR PANEL CONTROLS AND INDICATORS

3-1. Scope of This Section

This section of the instruction manual will describe the function of each control and indicator on the 444, as well as identify all connectors and corresponding signals that appear on the front and rear panels of the instrument.

3-2. INPUT AMPLITUDE - The Input Signal Controls

A. BNC Connector and
TEST/INPUT SIGNAL Switch

The analog input signal to be analyzed is applied to the BNC connector. The signal is either AC or DC, coupled to the input circuits. Caution: The maximum input, DC plus AC component of the signal should not exceed ±50 volts. Do not apply line voltage to the input. Severe damage will result. The lower frequency 3 dB point due to AC coupling is less than 0.5 Hz.

When the TEST/INPUT SIGNAL switch is in the TEST position, an internally generated test signal is coupled into the

input circuits. The amplitude of the signal is approximately 100 millivolts rms, and its frequency is 64 percent of the selected FREQUENCY RANGE. When this switch is in the AC or DC position, the signal applied to the INPUT SIGNAL BNC connector is fed into the input circuits.

B. SENSITIVITY Switch

This seven position switch controls the input sensitivity over a 100 to 1 (40 dB) range. Full scale sensitivity of 100 mv, 200 mv, 500 mv, 1, 2, 5 and 10 volts are available with the 1V position designated as 0 dB. All voltage levels are root mean square (rms). The optimum setting of the SENSITIVITY switch will generally be determined by the OVERLOAD indicator. If the indicator is on, the input circuits are being overdriven and will generally yield spurious components in the spectrum. The optimum setting is the lowest input sensitivity without an overload indication.

C. INPUT WEIGHTING Switch

This two position rotary switch permits the selection of either normal (flat) or A-weighted input. A-weighting is in accordance with A.N.S.I. specification S1.4-1971 (specifications for sound level meters) type 1. The A-weighting is implemented by weighting (shaping) the spectrum output and will not affect the INPUT AMPLITUDE indicators or the OVERLOAD indicator. A-weighting will only function in the 5 kHz, 10 kHz, 20 kHz, and 50 kHz frequency ranges. In all other ranges it will automatically be turned off.

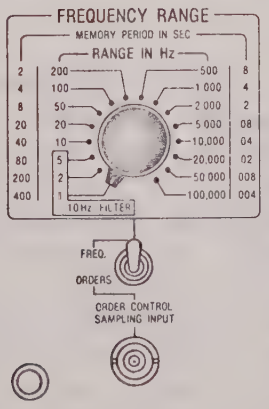
D. AMPLITUDE "LEDs"

This group of four LED (light emitting diode) indicators provides amplitude information on the input signal after the SENSITIVITY control. Illumination of any indicator signifies that the signal being analyzed is greater than the corresponding level. Thus, when the -18 dB indicator is on and the -12 dB indicator is off, the input signal is between -12 and -18 dB below full scale input. When a particular indicator in this group is on, all indicators below it must also be on. A-weighting which is done at the output of the Model 444 (in the frequency domain) does not affect the LEVEL indicators.

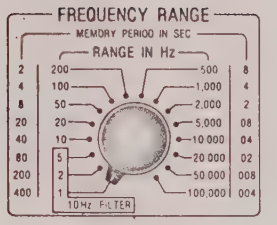
E. OVERLOAD "LED"

This indicator is on whenever the input signal amplitude causes limiting in the analog-to-digital converter, causing distortion in the output spectrum. When overload is detected, the indicator is held on for a pre-set time so that an overload condition, which occurs at intervals of approximately 0.5 second or less, will cause the indicator to remain on continuously.

3-3. FREQUENCY RANGE Controls

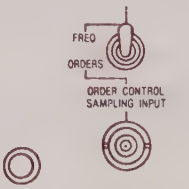


A. FREQUENCY RANGE Control



This control is used to select the cutoff frequency of the input lowpass filter and the internal sampling frequency (equal to 2.56 times the selected range). The switch contains two legends: one is the frequency RANGE IN HZ, and the other is the MEMORY PERIOD IN SEC. The latter reading is valid only when internal sampling is selected, or when the external sampling frequency is 2.56 times the FREQUENCY RANGE. The memory period is always equal to 1024 times the sampling period.

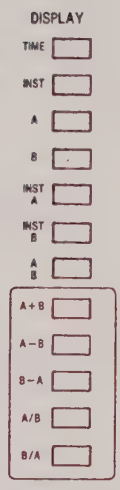
B. FREQ/ORDERS Switch and ORDER CONTROL SAMPLING INPUT Connector



The FREQ/ORDERS is a two position switch. In the FREQ position, sampling is controlled by a crystal oscillator in the 444 and the sampling frequency equals 2.56 times the FREQUENCY RANGE. In the ORDERS position, sampling is determined by an external input, which may be derived from the same mechanical device as the analog input signal to be processed, thereby tracking any frequency fluctuation created by speed variation of the mechanical device.

The ORDER CONTROL SAMPLING INPUT is a BNC connector, to which the external sampling frequency signal is applied. If the signal to be processed is derived from a rotating machine, the sampling input frequency may be the fundamental or any order of this fundamental. The ORDER CONTROL SAMPLING INPUT requires a minimum signal level of 1V peak to peak. The maximum frequency of the sampling input signal is 256 kHz (100 kHz FREQUENCY RANGE). The ORDER CONTROL SAMPLING INPUT signal is shaped by the internal waveshaping circuits of the 444, thereby allowing the use of any periodic waveform as an input. Maximum input signal is 10 volts peak to peak. Do not apply line voltage to this input. Severe damage will result.

3-4. DISPLAY - Mode Controls



This group of 12 interlocking switches is used to select the output to be displayed on the 444 CRT display. Each of the pushbuttons operates as follows:

1. TIME - When this button is depressed, the display consists of time data stored in the input buffer memory, from which the spectrum is derived. This data is always displayed with both linear vertical and linear horizontal scales.

2. INST - This switch position selects the display of the instantaneous spectrum data from the processed input data block. As the input data is updated via new samples, the spectrum derived is correspondingly updated. When the 444 is in HOLD, (see paragraph 3-10A), the INST display will exhibit no variation since it is derived from a fixed block of stored input data. The INST display can be presented on either linear or logarithmic vertical or horizontal axes.

3. A - In the A position, the display represents the averaging of successive, 50 percent redundant spectra in each of the 400 averager memory locations. Averaging is performed by calculation of the square of each spectral point prior to averaging. Upon completion of averaging, the square root of each averaged spectral point is displayed. The A averager data may be displayed in linear or logarithmic vertical and horizontal scales. Data stored in the A averager memory may be transferred to the B averager memory by means of the TRANSFER pushbutton described in paragraph 3-5C.4. There are separate A memories for narrowband and octave (optional) spectrum displays.

4. B - This switch position selects the display of the B averager memory. The B averager memory serves as a temporary storage memory where a spectrum may be stored for reference or for computation. Spectra cannot be accumulated directly in the B memory but must be transferred from the A memory via the TRANSFER control (paragraph 3-5C.4). Once a spectrum is stored in the B memory, it can only be erased by writing over it with another transfer operation.

There are also separate B averager memories for narrowband and octave (optional) spectrum displays.

5. $\frac{\text{INST}}{\text{A}}$ - This position of the display switch selects a dual display. The upper trace is the instantaneous spectrum and the lower trace is the averaged spectrum from the A averager memory.

6. $\frac{\text{INST}}{\text{B}}$ - This position like the previously described switch selects a dual display. The instantaneous spectrum will be displayed above the spectrum stored in the averager memory.

7. $\frac{\text{A}}{\text{B}}$ - This position selects a dual display with contents of averager memory A displayed above the contents of averager memory B.

8. A + B - When this position is selected, the arithmetic sum of the contents of averager memory A and averager memory B is computed and displayed. This computation does not change the contents of either memory and the summation is not stored.

9 and 10. A-B and B-A - These positions select the arithmetic difference of the averager A and B memory contents. As in the previously described mode setting, the averager memories are not altered, and the results of the computation are not stored. Negative results are not displayed but are forced to zero. Care in the selection of the A-B or B-A positions is required to minimize errors due to negative differences.

11 and 12. A/B and B/A - In these positions the ratios of the spectra contained in the A and B averager memories are computed. In the event that the denominator function goes to zero, the displayed result limits at full scale. Similarly, if the numerator function is zero, the result goes to zero. If both functions are zero, the displayed resultant is zero.

In all the computational modes, the B averager memory contents are scaled to the same SENSITIVITY setting as that used during the accumulation of the A averager memory contents. For example, suppose a spectrum were averaged with a SENSITIVITY setting of 10 volts rms and transferred to the B averager memory, followed by another average with a SENSITIVITY setting of 1V rms. Then the B averager contents will be multiplied by a factor of 10^2 prior to doing any computation.

3-5. SPECTRUM AVERAGE Controls

This group of switches and indicators provides the necessary control and monitoring function for the spectrum averager of the Model 444.

A. MODE -
SUM/DIFF/EXPON/PEAK

This group consists of four interlocked pushbutton switches. Each of the four settings determines a unique processing mode in the averager. NOTE: A significant increase in the averaging speed can be obtained by turning both the CURSOR switch and the rear panel ANNOTATION switch to the OFF position.

1. SUM - Successive 50 percent redundant spectra are added and stored in the averager memory on a cell-by-cell basis. A 50 percent redundant spectrum is defined as one obtained from a set of 1024 input time data points, 512 of which were used to derive the previously averaged spectrum. At higher analysis ranges (above 2 kHz) redundancy approaches zero. In the SUM averaging mode, averaging will continue until N spectra have been accumulated, where N is determined by the setting of the NUMBER-N switch.

2. DIFF - In this mode of averaging, successively averaged spectra are subtracted from whatever values have been stored in the averager memory prior to the start of this mode. If the result of the subtraction is negative, it is stored in the averager memory as a negative number, but the display will indicate a zero value. This mode is useful in minimizing the effect of background noise on a signal spectrum.

3. EXPON - This is a weighted summation mode, where recent spectra are more heavily weighted than older spectra. The weighting window is exponential with a constant equal to the setting of the NUMBER-N switch. For example, if the NUMBER-N switch is set to 128, then the 128th averaged spectrum before the currently averaged one is weighted by approximately .37 of its original value. Alternatively, the constant N indicates the number of averages required to bring the averaged value to 63 percent of its final value. The actual time constant corresponding to the N constant is determined by the time between non-redundant spectra.

4. PEAK - In this mode, each spectral value is examined and those spectral values that exceed values previously stored in corresponding locations are replaced. Thus, each location in the averager memory contains the largest value of the spectral point that occurred during the N spectra observed. The examination of each of the 400 new spectral values and the decision to store new peak values occurs at the same rate as SUM averaging.

B. NUMBER-N -
1/2/4/8/16/32/128/256/512/CONT

This switch selects the number of spectra averaged in the SUM, DIFF, or PEAK modes. The averaging process is automatically terminated and the output normalized when the pre-set number of spectra have been processed. When the CONT setting has been selected, the processing continues and the output is normalized as if 1024 were selected. In the EXPON mode, this switch sets the RC time constant. After the selected number of spectra have been averaged, the average value is 63 percent of its final value.

C. CONTROL -
START A/STOP A/CONT A/TRANS A→B

This group of momentary contact switches is used to control the Spectrum Averager.

1. START A - Depressing this button will erase the average A memory, except in DIFF mode where the averager memory is not erased, reset the NUMBER-N counter and start the averaging process.

2. STOP A - This button, when depressed, will stop the averaging process.

3. CONT A - If the averaging process has been stopped prior to reaching the preset NUMBER-N setting, then depressing the CONT A button will start the averager from the point at which it has been stopped and continue until it reaches the NUMBER-N control setting.

If the averager has accumulated the preset NUMBER-N of spectra, then depressing the CONT A button will cause the averager counter to be reset to zero (without erasing the averager A memory) and the averaging process will take another set of N spectra.

4. TRANSFER A→B - This button when depressed will transfer the current contents of averager memory A into memory B. The contents of memory A will not be altered by this operation. This is the only way in which the contents of memory B can be modified.

D. IN PROCESS

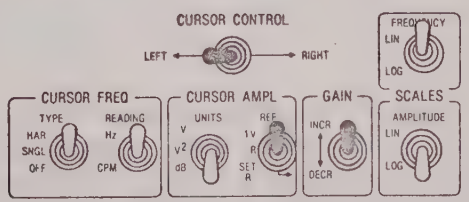
This LED indicator warns that an averaging cycle is in process. During the averaging cycle, this indicator flashes (the rate of flashing is not related to the averaging rate). However, there are exceptions in the following settings:

NUMBER-N/CONT - In this position, in all averaging modes, the IN PROCESS LED will continue to flash, even after the first 1024 spectra have been analyzed. Depressing the STOP pushbutton will stop averaging in this position.

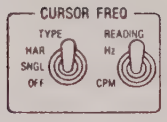
EXPON - After reaching the N constant selected by the NUMBER-N switch (except in the NUMBER-N/CONT position), the IN PROCESS indicator will remain illuminated, and averaging continues until the STOP pushbutton is depressed.

This indicator is normally off prior to initiating an averaging process and after completing the cycle.

3-6. The Display Controls



A. CURSOR FREQ - TYPE/READING



1. READING - Hz/CPM - This switch is used to obtain a cursor frequency readout in either Hz (Hertz) or CPM (cycles per minute), the latter being equal to 60 times the value in Hz. This control will function only when the cursor type switch is in either the SINGL or HAR position. The annotation field used to indicate the setting of the FREQUENCY RANGE switch will always read in Hz regardless of the setting of the READING-Hz/CPM switch.

2. TYPE - HAR/SINGL/OFF - This three position switch controls the display of a vertical cursor line on the CRT and the assocaited readout of amplitude and frequency.

OFF - In this position, the vertical cursor line, as well as the displayed values of amplitude and frequency, are turned off. (Except in the "AT CURSOR" or "PLOT" mode, see section 3-8, when the cursor line is on but the displayed values are off.)

SINGLE - In this position, a vertical line is generated from the top of the graticule to the bottom of the graticule at a frequency determined by the CURSOR CONTROL. The intersection of this cursor with the spectrum display will be intensified, unless the spectrum display is at a limiting value (i.e., full scale or zero) in which case there will be no intensification. (In "AT CURSOR" or "PLOT" modes the dot is always presented.) The amplitude of the intensified point of the spectrum display will be displayed in the annotation. The value displayed will be determined by the selection of the CURSOR AMPLITUDE and AMPLITUDE SCALE switches.

The horizontal coordinate of the cursor will be read out in Hz, CPM, or percent full scale according to the setting of the READING and FREQ/ORDERS switches.

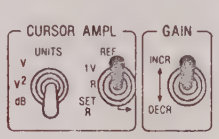
HAR - In this position, the cursor is generated as above; in addition, at frequency addresses that are multiples of the cursor frequency address, the displayed spectrum point will be intensified. At the second harmonic address, two points (harmonic address plus address immediately following) are intensified. At the third harmonic address, three points

are intensified; at the fourth harmonic address, four points are intensified; for the fifth and higher harmonic addresses, five points are intensified. The increasing number of addresses intensified are required to identify harmonics of a signal frequency, since any slight offset of the fundamental from the center of the frequency analysis cell will result in a shift of a number of cells at higher harmonics. Note that in the "PLOT" mode no harmonic dots are displayed.

B. CURSOR CONTROL - LEFT/RIGHT

This is a center off momentary LEFT/RIGHT type switch. The LEFT position controls cursor motion to the left; the RIGHT position controls cursor motion to the right. The cursor will "single step" when the switch is activated in the RIGHT or LEFT positions for less than approximately two seconds. If held in either position for longer than two seconds, the cursor will slew at a rate of approximately 16 seconds per display span. This control is inoperative if in the "PLOT" mode.

C. CURSOR AMPL and GAIN



1. UNITS - This switch selects the units in which the CURSOR AMPLITUDE data is displayed. Units selectable are volts, V, volts squared, V^2 (power), and dB relative to the reference level selected by the REF switch. This control is functional only if the cursor is on.

2. REF - The reference levels for the UNITS switch are selected by the REF switch. This is a three position toggle switch where the lower SET R position is a momentary contact. Note that this switch will only function when the cursor is on. A fixed reference of 1V (equivalent to a 1V rms sinusoidal input) and a variable reference are available. When a 1V reference is selected, the cursor reads equivalent input signal levels in volts, $volts^2$, or dBV (dB with respect to 1V).

The variable reference level may be set in either of two ways:

a. To set the reference to a particular level on a spectrum display use the CURSOR CONTROL to move the

intensified dot of the cursor to the desired reference point on the spectrum. Depress the REF switch momentarily into the SET R position. The cursor readout is now relative to the level of the spectrum at the cursor location. If the UNITS switch is in the V position, then the cursor readout will be in units of R, if in the V^2 position, the readout will be in units of R^2, and if in the dB position the readout will be in dB relative to the SET position. For example, if the reference level were set on a spectral line whose absolute value was 0.5 volts, the readings for the three unit switch settings would be 1.00R, 1.00R^2, and 0 dBR. If the cursor were moved to read another spectral peak of double the amplitude, the three readings possible would be 2.00R, 4.00R^2, and 6 dBR. The original value of the set reference level is also displayed as 0.5V/R.

b. To set a reference to an arbitrary reference level depress and hold the REF switch in the SET R position. Observe the reference level field in the annotation (recognizable by its units, V/R). Note that the reference readout field of the display will change to the value of the spectrum at the cursor location. The GAIN control is used to change the reference level. Placing the GAIN control in the INCR position will cause the reference level to decrease. Similarly, holding the GAIN control in the DECR position will cause the reference level to increase. The range of possible reference values is from 1.00×10^{-9} to $999. \times 10^{-9}$. In order to enable the operator to cover this range quickly the GAIN control is a dual rate control. Holding the control in either position will cause the reference level to change at a relatively slow rate for the first one hundred counts; after this the reference level will change quite rapidly in order to cover a wide range of values quickly. After reaching the desired reference level simply release the GAIN control and REF switch and allow them to return to their neutral positions. Note that once the REF switch is released the reference level is fixed. If the REF switch is placed in the SET R position again, the existing reference level will change to the preset cursor amplitude level. All cursor levels will now be relative to the reference level R as described previously.

3. GAIN - This control is used in conjunction with the REF switch to set an arbitrary reference level as described above. It may also be used to control display GAIN. Holding the GAIN control in the INCR position will cause the display GAIN to increase in 10 dB steps for a LOG AMPLITUDE scale, and by factors of two for a LINEAR AMPLITUDE scale to a maximum of 50 dB or 512. It will take approximately one second for each

change in GAIN to be observed. In a like manner, holding the control in the DECR position will cause an attenuation of the display to a maximum of -50 dB or 1/512 depending on the AMPLITUDE SCALE selected. Refer to Section V for further details on the use of these controls. Display GAIN is annotated on the CRT display. Refer to paragraph 3-12 for details.

D. SCALES -
FREQUENCY/LIN/LOG
AMPLITUDE/LIN/LOG

1. FREQUENCY - The selection of a linear or logarithmic frequency axis is made using this switch.

In the LIN position, the horizontal axis represents equal spacings of 400 readout addresses. In the LOG position, the horizontal axis is scaled so that equal increments along this axis represent equal address ratios (e.g., the spacing between the 5th and 10th address will be the same as the spacing between the 10th and 20th address, as well as between the 200th and 400th address). When viewing TIME data, the horizontal axis will always be linear.

2. AMPLITUDE - This switch is active when viewing any output except TIME. (Only linear vertical scale is permitted when viewing TIME.)

In the LIN position for single displays, the graticule is divided into ten equal divisions with zero linear amplitude coinciding with the bottom graticule line, a full scale linear amplitude coinciding with the top graticule. In the dual display modes (i.e., INST/A, A/B, etc.), the vertical scale consists of two scales of ten equal spaces stacked one above the other. The center line (10th division) is the 0 level for the upper display and the full scale level for the lower display.

The linear amplitude scale has basic units of volts and represents the square root of the power spectrum. When using the LIN amplitude scale in conjunction with the GAIN control, gains of 1, 2, 4, 8, 16, 32, 64, 128, 256 and 512 are provided as well as attenuations of 1, 1/2, 1/4, 1/8, 1/16, 1/64, 1/128, 1/256, 1/512.

In the LOG position, the vertical scale is divided into six divisions, each division representing 10 dB, or two displays each with six divisions. The definition of 10 dB is a voltage ratio of 3.16:1, or a power ratio of 10:1. The six divisions, therefore, provide a viewing range of 60 dB, or 1000:1 voltage ratio, or one million-to-one power ratio. When the AMPLITUDE SCALE switch is in the LOG position, the GAIN control can be used to provide offsets of -50 to +50 dB in 10 dB steps. The LOG display will always extend over a 60 dB range but the maximum (full scale) point of the range may be offset by the GAIN control setting, as annotated to the left of the displayed graticule above the dB indication. The LOG AMPLITUDE SCALE setting is inoperative in the VIEW TIME switch setting. When viewing time data, the vertical axis will always be linear. For example: The GAIN control setting is at -10 dB. The top graticule line now represents +10 dB relative to the full scale setting of the SENSITIVITY control. Cursor readings are not affected by the AMPLITUDE SCALE or GAIN control settings.

3-7. RESOLUTION

This series of interlocked pushbutton switches is used to select the desired frequency resolution of the displayed spectrum.

A. 400 LINE - This position is used to select narrowband spectrum. The frequency resolution is 1/400 of the frequency range.

B. 1/3 OCT - (Optional) In this position a spectrum with 1/3 octave resolution is synthesized from the narrowband spectrum. Center frequencies, bandwidths and effective filter rolloffs meet ANSI Class III standards. When 1/3 octave resolution is selected, the frequency range is forced to the nearest 1/3 octave compatible range. The following table summarizes the 1/3 octave compatible frequency ranges and the characteristics of the 1/3 octave filters synthesized in each range:

1/3 octave:

Range Setting	Center Freq. Range (Hz)	(ANSI Std. 1/3 oct. band numbers)	Approx. Processing Time (sec)
5K	6.3 - 5,000	(Band 8 - 37)	2.4
10K	12.5 - 10,000	(Band 11 - 40)	1.2
20K	25 - 20,000	(Band 14 - 43)	.8
50K	50 - 40,000	(Band 17 - 46)	.8

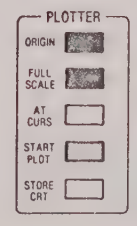
C. 1/1 OCT - (Optional) In this position a 1/1 octave spectrum is synthesized from the 1/3 octave spectrum. 1/1 octave filters meet ANSI Class II standards for all the filter characteristics described previously. As in the 1/3 octave resolution mode, selection of 1/1 octave mode will force the frequency range to the nearest 1/1 octave compatible range. 1/1 octave compatible frequency ranges are summarized below:

1/1 octave:

Range Setting	Center Freq. Range (Hz)	(ANSI Std. 1/1 oct. band numbers)	Approx. Processing Time (sec)
5K	8.0 - 4,000	(Band 9 - 36)	2.4
10K	16.0 - 8,000	(Band 12 - 39)	1.2
20K	31.5 - 16,000	(Band 15 - 42)	.8
50K	63 - 31,500	(Band 18 - 45)	.8

In either 1/3 octave or 1/1 octave modes, selection of TIME DISPLAY mode will result in an error message, "1/3 OCT" or "1/1 OCT" on the display CRT.

3-8. PLOTTER



This group of pushbutton switches controls the output on the rear panel PLOTTER outputs.

A. ORIGIN - When this switch is depressed, the X and Y plotter outputs are forced to the origin of the display. Pen lift contacts will be in the open condition (pen up).

The CRT display will remain unchanged except for the appearance of an intensified dot at the spectrum origin point (lower left hand corner of the graticule).

B. FULL SCALE - Depressing this pushbutton will result in the X and Y plotter outputs being forced to the full scale-full scale (upper right corner) point of the display. Pen-lift contacts will be open (pen up). An intensified dot will appear at the equivalent point on the CRT display.

C. AT CURS - When this switch is depressed the X and Y plotter outputs will read the current spectrum value at the display cursor location. The pen-lift contacts will be open (pen up). Even if the cursor is off the cursor line will be displayed.

D. START PLOT - When this pushbutton is depressed, the following sequence of events will occur.

1. The cursor which will be displayed in this mode, even if the cursor switch is off, will move to the extreme left hand graticule location on the CRT display, and pause.

2. Pen will drop.

3. The cursor will begin moving to the right, and the X and Y plotter outputs will track the spectrum or time value at the cursor location.

4. When the cursor reaches the right hand graticule limit, the pen-lift contacts will open (pen up) and the cursor will stop.

No further cursor control will be possible until the unit is taken out of the plotter mode by depressing the AT CURS, ORIGIN or FULL SCALE button.

E. STORE CRT - This position provides a single slow readout of the entire display to an external device as selected by the STORE MODE slide switch on the rear panel.

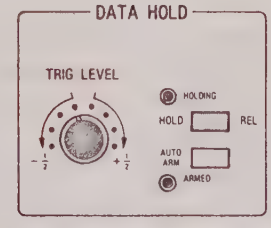
Upon completion of a single sweep, the display will automatically return to normal CRT display until the STORE CRT pushbutton is depressed again.

3-9. I.D. NUMBER

This digital switch is used to enter a four digit identification number in the lower left hand corner of the CRT display annotation. This I.D. number is easily recognized in the annotation by the number sign (#) which follows the four digit number.

Model 444-263, equipped with the optional FREQUENCY EXPANSION unit, uses the ORIGIN FREQUENCY switch to enter the I.D. number when the I.D. # control is in the ON position (FREQUENCY EXPANSION is OFF).

3-10. DATA HOLD



A. DATA HOLD

1. HOLD/REL - This momentary pushbutton switch provides alternate action to inhibit or allow collection of input data samples in the input buffer memory. There are no sample delays or threshold levels involved in the HOLD/REL operation, as with the AUTO ARM. Consequently, if the 444 is in the ARMED state and the HOLD/REL button is pressed, the system will go into HOLD immediately, and the previous 1024 samples are "frozen" in the input buffer memory. Pressing the HOLD/REL button a second time places the system in its released mode immediately.

2. HOLDING - This indicator is on whenever the system has been placed in a HOLD state due to transient capture or manual HOLD action.

3. AUTO ARM - This momentary pushbutton switch arms the threshold detection circuits to recognize the point

at which the input signal crossed the trigger level setting. When this point is detected, 896 additional samples are collected. Further collection of data samples is halted at this point. The threshold point is therefore represented by the 128th sample stored in the input buffer memory, which always holds the most recent 1024 samples collected.

4. ARMED - This indicator is on from the time that the AUTO ARM is activated until the TRIG LEVEL is exceeded, or until the HOLD/REL momentary action button is pressed.

B. TRIG LEVEL

This is an eight position switch used to control the threshold level of an input signal to be detected when capturing a transient. This switch is effective only when the AUTO ARM button is pressed. The maximum counter-clockwise position is set for -1/2; i.e., when the signal threshold is equal to or less than (algebraically) -1/2 full scale, the trigger level will have been exceeded. The next three positions are -1/4, -1/8, and -1/16, respectively. The following four positions are +1/16, +1/8, +1/4, and +1/2.

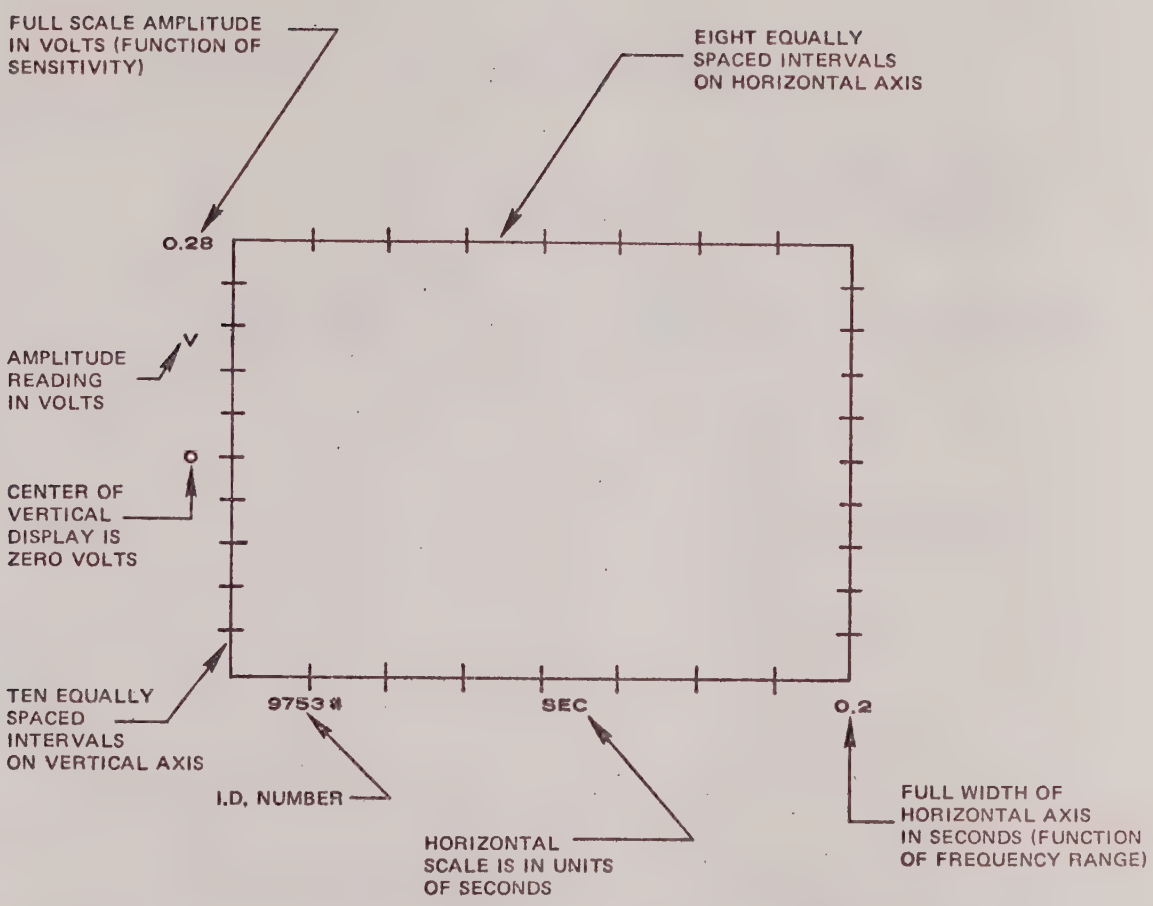
3-11. POWER

This control is used to turn the unit ON and OFF. The LED indicator will be illuminated when the unit is in the ON mode.

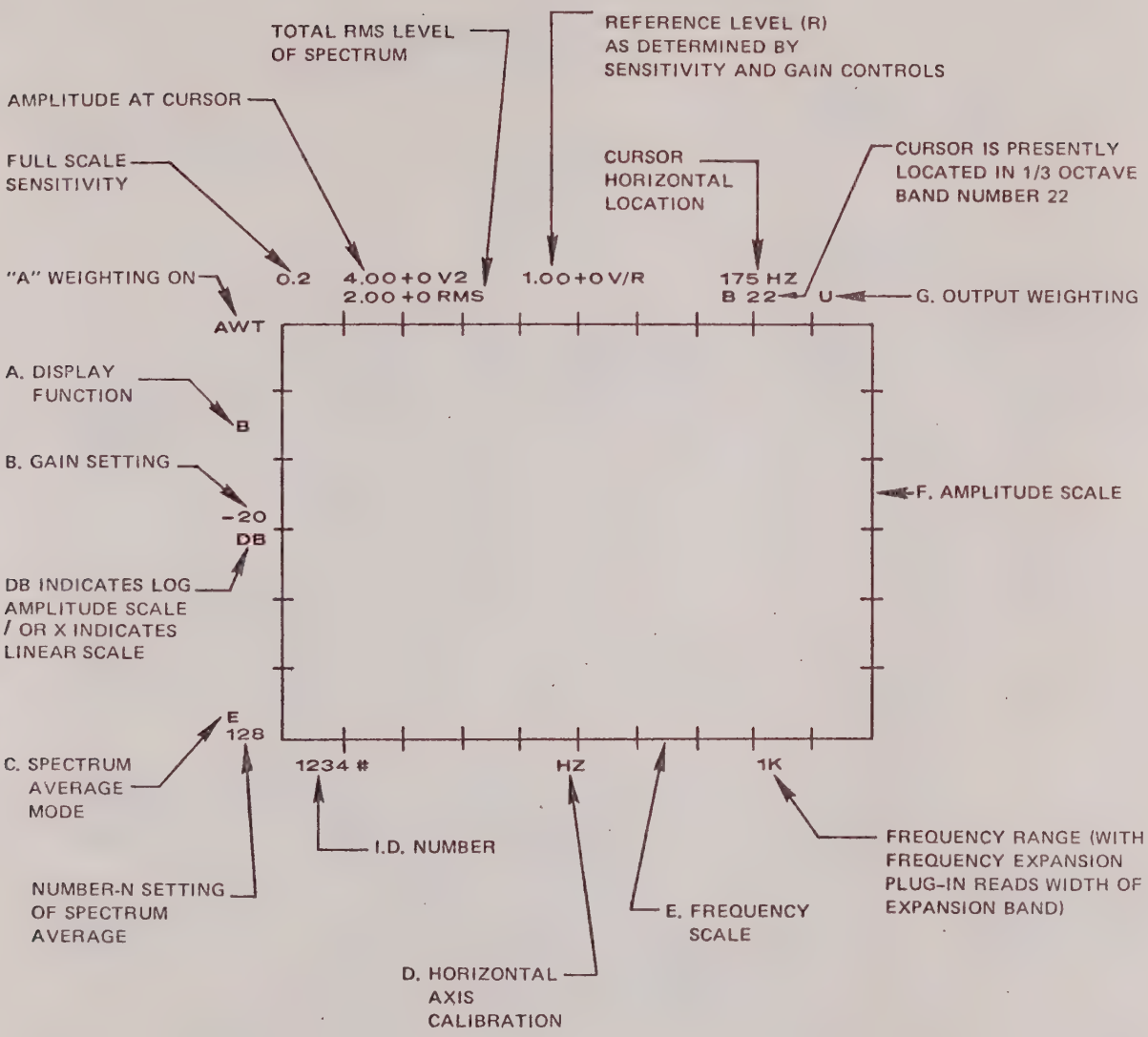
3-12. The CATHODE RAY TUBE (CRT) - The Display

The CRT display consists of an electronically generated graticule, a series of annotation fields which describe the control settings and the 444 output display. The following typical displays are used to describe the location and function of each annotation field. A series of tables follow the illustrations which describe each of the listings within the fields which have more than one possible indication. Letters appearing on the illustrations refer to the appropriate entry in the tables.

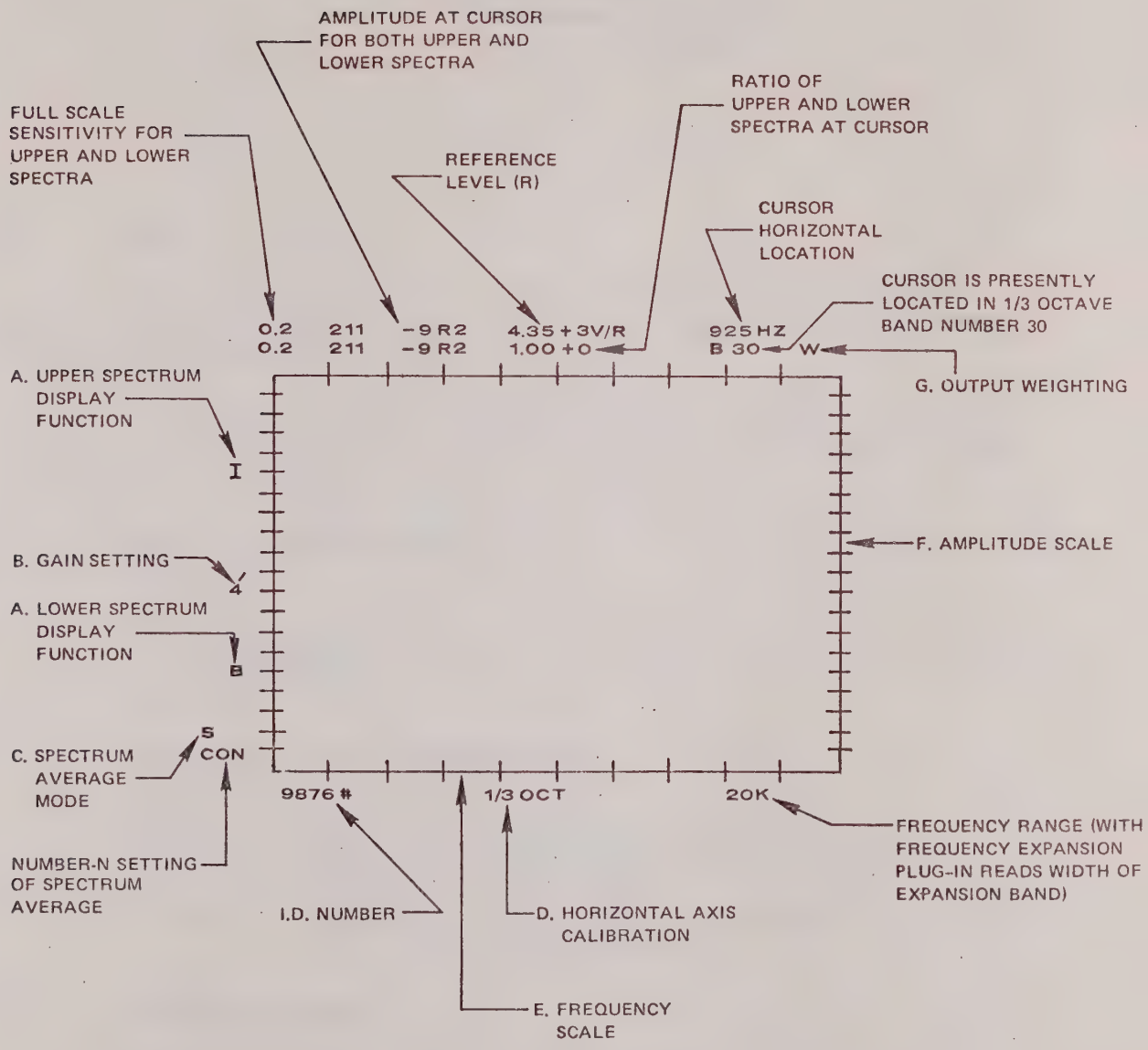
TIME DISPLAY


FULL SCALE AMPLITUDE IN VOLTS (FUNCTION OF SENSITIVITY)
EIGHT EQUALLY SPACED INTERVALS ON HORIZONTAL AXIS
0.28
AMPLITUDE READING IN VOLTS
V
0
CENTER OF VERTICAL DISPLAY IS ZERO VOLTS
TEN EQUALLY SPACED INTERVALS ON VERTICAL AXIS
9753 #
I.D. NUMBER
SEC
HORIZONTAL SCALE IS IN UNITS OF SECONDS
0.2
FULL WIDTH OF HORIZONTAL AXIS IN SECONDS (FUNCTION OF FREQUENCY RANGE)

SINGLE SPECTRUM DISPLAY



DUAL SPECTRUM DISPLAY



A. DISPLAY FUNCTION

Display Mnemonic	Display Mode
V (volts)	TIME
I	INSTaneous Spectrum
A	Averager A Memory
B	Averager B Memory
A + B	A + B
A - B	A - B
A/B	A/B
B/A	B/A

B. GAIN

Log Amplitude Scale - -50 to +50 dB (in 10 dB increments) indicates amplitude of upper horizontal graticule line relative to SENSITIVITY control setting.

Lin Amplitude Scale - x512 to /512 (in powers of two) indicates factor by which full scale display amplitude has been multiplied or divided.

C. SPECTRUM AVERAGE MODE

S - SUM
D - DIFFerence
E - EXPONential
P - PEAK

D. HORIZONTAL AXIS CALIBRATION

(Hz) - frequency in Hertz
1/3 OCT - 1/3 OCTave RESOLUTION - Three 1/3 octave filters per division
1/1 OCT - 1/1 OCTave RESOLUTION - One octave filter per per horizontal division

E. FREQUENCY SCALE

Log Frequency - 3 decade divisions full scale, 0.1 full scale, 0.01 full scale

Lin Frequency - 10 equal divisions

F. AMPLITUDE SCALE

Log Amplitude - Six (6) equal divisions (10 dB/div) per display

Lin Amplitude - Ten (10) equal divisions per display

G. OUTPUT WEIGHTING

W - Hanning (continuous) Weighting
U - Uniform (transient) Weighting

3-13. STORE MODE (Rear Panel)

This switch is used to select the appropriate store CRT display for specific external recording devices.

A. CRT - In this position the store CRT mode will output data to a Tektronix Model 613 Storage Display unit via the rear panel external display X and Y and the Model 613 Z axis BNC connector.

B. PLOT - In this position the 444 will output data to a Tektronix 4000 Series terminal or 4662 digital X-Y plotter via the connector J103.

C. AUX - In this position the 444 will input or output data from the external peripheral units summarized in the following table. In each case the appropriate setting of the hexadecimally coded switches (located on the ENCODER board at location E32) necessary to format data properly, is also given.

3-14. External Peripheral Selection

PERIPHERAL	SWITCH E32 SETTING		
	Fast Peak Averager*	Normal Peak Averager	Rear Panel Interface Connector
1. 144 Digital Cartridge Recorder	0	8	J101 and J102
2. Start Paper Tape Reader	1	9	J101 and J102
3. RS232 Output			
a. Sense and real/ imaginary dump	2	A	J103
b. Sense and spectrum or time	4	C	J103
c. Sense, real/ imaginary dump and spectrum or time	6	E	J103
4. Paper Tape Punch			
a. Sense and real/ imaginary dump	3	B	J101 and J102
b. Sense and spectrum or time	5	D	J101 and J102
c. Sense, real/ imaginary dump and spectrum or time	7	F	J101 and J102

*Note: In fast peak averager mode, averager is updated at the processing rate rather than the 50 percent redundancy rate normally used.

3-15. WEIGHTING WINDOW (Rear Panel)

A. FLAT - This position of the switch leaves the input data block unweighted (or uniformly weighted) and provides a slow rolloff of the effect of any single point in the frequency domain due to the finite length of input signal processed.

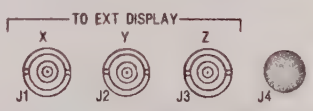
B. HANN - In the HANN position of this switch, the input data block is weighted, or multiplied, by the function $\sin^2 \pi n/1024$, where "n" represents the position of the sample in the 1024 data block. This weighting function is also referred to as Hanning weighting and provides for a sharper rolloff of the signal in the frequency domain due to the finite length of the input signal, than that provided by uniform weighting.

C. AUTO - In this position the flat weighting function is automatically selected whenever the AUTO ARM pushbutton is depressed. This automatically prepares the unit for analysis of transient data. When the HOLD function is cleared, the weighting is returned to the Hanning weighting.

3-16. RESET (Rear Panel)

This pushbutton switch is a master reset for the 444 processor. Depressing this button will reinitialize the system program and clear the A averager memory.

3-17. TO EXT DISPLAY
X, Y, Z BNC Outputs



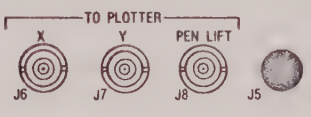
The outputs at these BNC connectors match the corresponding signals to the internal CRT and have the following nominal voltage levels:

A. J1 - X - Horizontal Output. 0 to +1 volt, analog. +1 volt corresponds to right of screen.

B. J2 - Y - Vertical Output. 0 to +1 volt, analog. +1 volt corresponds to top of screen.

C. J3 - Z - Z-axis (intensity axis) Output. 0 to -2 volts, digital. 0 volts should turn beam on; (-2 volts should turn beam off). (Internal jumpers allow other polarities and levels.)

3-18. TO PLOTTER
X, Y, PEN LIFT
BNC Output



These connectors are used in the plotting mode and provide the X and Y analog output signals to the plotter, as well as a Pen Lift signal used to activate the pen when plotting. The signals are defined as follows:

A. J6 - X - Horizontal Output. This signal goes from 0 to +3.2 volts while plotting.

B. J7 - Y - Vertical Output. This signal goes from 0 to +3.2 volts.

C. J8 - PEN LIFT. This is a relay contact closure during plotting. Contacts are open at all other times.

When the AT CURS button of the PLOTTER mode switch group is depressed (front panel), the voltages at the X and Y plotter outputs reflect the current cursor locations. PEN LIFT - up.

3-19. AVG TRG OUT/ARM TRG IN
613 Z AXIS BNC Connectors

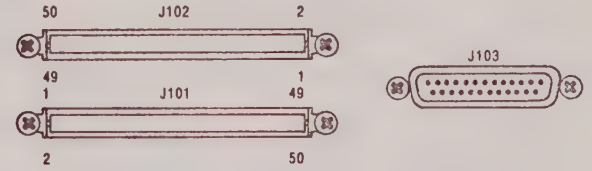
A. J9 - AVG TRIG OUT - This is a digital signal indicating that the 444 input buffer memory has been read out and is available for loading new data. The signal is normally in the high state (+2.5 to +5.0 volts) and goes low (0 to +.7 volts) for 1/2 microsecond when the input buffer readout is complete.

B. J10 - ARM TRG IN - A digital input pulse at this connector will arm the circuits in the -10 Plug-In unit to accept an input signal above the threshold level established by the TRIG LEVEL front panel control which will place the 444 into HOLD after the following 896 samples. The pulse is a normally high level and goes low for at least 1 microsecond. It is the

low to high (trailing edge) transition that will cause the arm operation. The pulse duplicates the effect of the AUTO ARM switch.

C. J11 - 613 Z AXIS - This is a logic output signal that is active during the readout of the spectrum into the 613 storage oscilloscope. The level is normally low and will go high during the 613 readout whenever a display point is to be written onto the 613 cathode ray tube.

3-20. J101, J102, and J103 Connectors



A. J101 - 50 pin connector with pin assignments as follows:

Pin	Mnemonic	Explanation
1	XDS0	External, bus multiplexer select code, bit 0
2	XDS1	External, bus multiplexer select code, bit 1
3	XDS2	External, bus multiplexer select code, bit 2
4	XDS3	External, bus multiplexer select code, bit 3
5	XDSEL	Forces bus multiplexer control to external code (XDS0 through XDS3)
6-25	XD0-XD19	External data input bus, bits 0 through 19
26-45	DX0-DX19	External data output bus, bits 0 through 19
46	$\overline{\text{X IN DATA WRITE PULSE}}$	.5 μsec high to low pulse whenever data is written into the input buffer memory
47	X INT AD EN	Controls source of data into input buffer memory: high = internal A/D converter data low = external data on DX bus

Pin	Mnemonic	Explanation
48	Ground	
49	$\overline{\text{DX READ}}$	Negative 2 μsec pulse signifying that the 444 is outputting data on the DX bus
50	D BUS EN	Normally high level enables DX0 through DX15

B. J102 - 50 pin connector with pin assignments as follows:

Pin	Mnemonic	Explanation
1	$\overline{\text{X 2 MS CLK}}$	High to low .5 μsec pulse every 2 msec
2	$\overline{\text{X PC LD INH}}$	Low level inhibits loading of program counter. Normally high to enable loading
3-7	$\overline{\text{X FLG 0 - X FLG 4}}$	Five flags individually activated by low levels to signal 440 for appropriate action
8	$\overline{\text{X HALT}}$	Forces system to repeat current logic step as long as signal is held low
9	$\overline{\text{X PADV EN}}$	When low inhibits all 440 logic steps and enables external stepping clock $\overline{\text{X PADV}}$
10	$\overline{\text{X PADV}}$	Enabled by $\overline{\text{X PADV EN}}$. Low to high transition causes the system to advance one logic step
11	LOAD PCX	High level indicates that Program Counter is being loaded
12	Z AXIS ON	High when Z AXIS ON, low when Z AXIS OFF
13	X AVG SWEEP	High level during spectrum or time data display
14	$\overline{\text{X LD PC}}$	Low input to load Program Counter
15	X LD PC SYNC	Synchronized version of Signal 14
16-25	PC0X - PC9X	Buffered Program Counter outputs 0 through 9
26	$\overline{\text{X STOP}}$	Pulse, high to low to high, input, parallels front panel STOP button activation
27	$\overline{\text{X CONT}}$	Pulse, high to low to high, input, parallels front panel CONT button activation

Pin	Mnemonic	Explanation
28	X RESET	Pulse, high to low to high, input, parallels front panel RESET button activation
29	X START	Pulse, high to low to high, input, parallels front panel START button activation
30	X HOLD/REL	Pulse, high to low to high, input, parallels front panel HOLD/REL button activation
31	X ARM	Pulse, high to low to high, input, parallels front panel ARM button activation
32	X BLK SYNC	Pulse, high to low to high, input, minimum 2 μsec low to clear Buffer Full level and input buffer sample counter
33	X BUFF FULL	Normally high output. Goes low whenever buffer is full. Returns to high level when X BLK SYNC is issued
34	X AD READY	Pulse, high to low to high, input; causes XD0 through XD10 to be written into input buffer whenever X INT AD EN is low
35	PC 10X	Buffered Program Counter, bit 10
36	STOP ON FULL	Low input causes input buffer to stop when full
37	X STB 0	Unassigned
38	X STB 1	Unassigned
39	X STB 2	Pulse used to transfer data to 66-2A
40	X PADV EN SYNC	Same as Signal 9 except inverted and synchronized to internal clock
41	X STB 3	Complement of AVG TRIG OUT BNC
42	PCBX	Program counter M.S.B.
43	X RTC INH	Display inhibit/plotter stall
44	GRD	Ground return
45	SMOOTHING INH	Low disables display smoothing
46	XCTRL	High to low transition activates peripheral devices on depressing STORE CRT button
47	AVG IN PROC	Low indicates averager processing

Pin	Mnemonic	Explanation
48	$\overline{\text{REM LED}}$	High to low transition from peripheral device to 444 to acknowledge acceptance of data and reset $\overline{\text{XCTRL}}$
49	$\overline{\text{X STOR CRT}}$	Remote store CRT input pulse high to low parallels front panel STORE CRT button
50	$\overline{\text{XA}\rightarrow\text{B}}$	Remote transfer A→B, pulse high to low parallels front panel transfer A→B

C. J103 - RS232C Interface Connector

Pin	Mnemonic	Explanation
1	FRAME GND	Frame (shield) ground
2	TRANSMIT DATA	Serial data into 444
3	RECEIVE DATA	Serial data from 444
4	REQUEST TO SEND	Signal from external device to 444 requesting access
5	CLEAR TO SEND	Signal from 444 to external device
6	DATA SET READY	This line is asserted when data is transmitted from the 444
7	SIGNAL GND	Signal ground return
8	CARRIER DETECT	Indicates 444 is in a POWER ON condition. Asserted when POWER ON.
9-25	NO CONNECTION	

SECTION IV

CHECKOUT PROCEDURE USING INTERNAL TEST SIGNAL

4-1. Scope of This Section

This section of the instruction manual contains a step by step procedure for checking the 444 using the internal TEST signal. Verification of the required result is seen on the display.

4-2. Initial Setting

Set the front and rear panel controls as indicated in Table 4-1.

4-3. Graticule Annotation Check

This section of the checkout procedure verifies correct operation of the annotation fields by echoing control settings on the CRT display.

A. Verify that the display on the CRT is the same as that shown in Figure 4-1. Change the setting on the I.D. Number digital switch (origin frequency in units equipped with Option -26). Verify that the I.D. number in the lower left hand corner of the display matches the I.D. number on the front panel. Note that in units equipped with the Option -26 Frequency Expansion the least significant digit is locked at zero and is not shown in the I.D. number field. Change each decade of the I.D. number digital switch through its entire range and verify that the I.D. number field of the display matches the switch setting in every case.

4-4. SENSITIVITY Control and AMPLITUDE Indicator Check

Note the full scale voltage amplitude field in the upper left hand corner of the display. This field should read 0.14V. Place the SENSITIVITY control in the 200 MV position. Note that the full scale voltage amplitude field now reads 0.28V and that the time waveform displayed on the screen has decreased to 1/2 amplitude. The -6 dB AMPLITUDE indicator may flicker or be extinguished at this point.

TABLE 4-1

CONTROL SETTINGS

CONTROL	SETTING
POWER	ON
INPUT AMPLITUDE	
TEST/AC/DC	TEST
AMPLITUDE Indicators	All ON
OVERLOAD Indicator	OFF
SENSITIVITY	100 MV (-20dB)
A-WT	OFF
FREQUENCY RANGE	10,000 Hz
FREQ/ORDERS	FREQ
DATA HOLD	REL
HOLDING Indicator	OFF
TRIG LEVEL	+1/2
AUTO ARM	OFF
ARMED Indicator	OFF
FREQUENCY EXPANSION (Optional)	OFF/I.D.# ON
CURSOR CONTROL	
CURSOR FREQ	OFF
READING	Hz
UNITS	dB
REF	1V
FREQUENCY SCALE	LIN
AMPLITUDE SCALE	LOG
RESOLUTION	400 LINE
PLOTTER	ORIGIN
SPECTRUM AVERAGE	
NUMBER	1
MODE	SUM
DISPLAY	TIME
REAR PANEL	
WEIGHTING WINDOW	HANN
ANNOTATION	FULL
STORE MODE	AUX
I.D. NUMBER (Origin Frequency in units equipped with -26 Option)	0000

FIGURE 4-1

Rotate the SENSITIVITY control to the positions shown in Table 4-2 below. In each case verify that the indicated change in the display and amplitude indicators are correct.

TABLE 4-2

SENSITIVITY	Full Scale Amplitude Annotation Field	Amplitude Indicator
500 MV	0.70	-6 OFF -18 ON
1V (0dBV)	1.4	-18 OFF -24 ON
2V	2.8	-18 OFF
5V	7.0	All Indicators OFF
10V	14.	All Indicators OFF

Return the SENSITIVITY control to the 100 MV (-20dBV) position.

4-5. FREQUENCY RANGE Check

Note the full scale time field in the lower right hand corner of the display. This field should read .04 SEC. Place

the FREQUENCY RANGE switch in each position given in Table 4-3 and verify the correct full scale time field annotation.

TABLE 4-3

FREQUENCY RANGE (In Hz)	Full Scale Time Field (In SEC)
100,000	.004
50,000	.008
20,000	.02
5,000	.08
2,000	.2
1,000	.4
500	.8
200	2
100	4
50	8
20	20
10	40
5	80
2	200
1	400

Return the FREQUENCY RANGE switch to the 10,000 Hz range.

4-6. CURSOR Check

Depress the DISPLAY INST pushbutton; the display should change. Verify that the graticule and annotation are the same as shown in Figure 4-2.

FIGURE 4-2

Place the CURSOR FREQ TYPE switch into the SNGL position. Note the appearance of a vertical cursor line and cursor annotation fields on the display. Verify that the cursor annotation fields are similar to those shown in Figure 4-3. The numerical values on the display may be different from those shown in Figure 4-3, but the same annotation fields must appear.

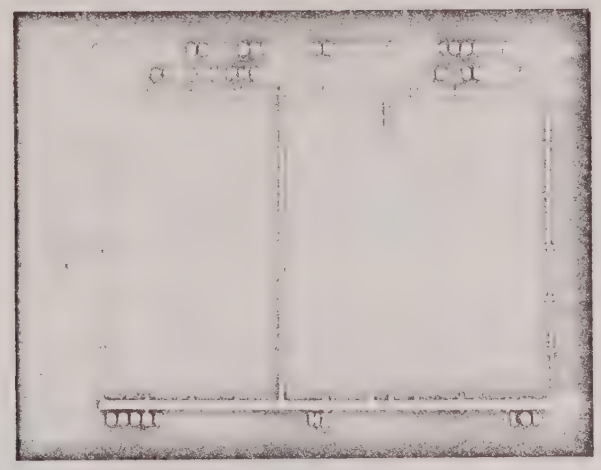


FIGURE 4-3

Momentarily push the CURSOR CONTROL lever switch to the right (do not hold the switch in this position). Notice that the cursor frequency readout field of the annotation (upper right hand corner of the display) increases by 25 Hz each time the CURSOR CONTROL is tapped to the right.

Momentarily push the CURSOR CONTROL switch to the left. Notice that the cursor frequency readout field decreases by 25 Hz each time the CURSOR CONTROL switch is activated. Note that the 25 Hz movement of the cursor frequency readout is a function of the FREQUENCY RANGE. Hold the CURSOR CONTROL switch to the right. The vertical cursor line will now move continuously to the right. The cursor frequency annotation field and the 1/3 octave band number field located immediately below it will also increase until the cursor line reaches the right hand edge of the display. When the cursor reaches the right hand edge of the graticule, it will "wrap around" and appear at the left hand edge of the display. At that time the cursor frequency annotation field and 1/3 octave band number will be reset. (For the 10,000 Hz FREQUENCY RANGE the cursor frequency annotation will read 25 Hz and the 1/3 octave band number will read 14 at the first cursor location to the right of the left hand graticule limit).

Hold the CURSOR CONTROL lever switch to the left. Verify that the vertical cursor line on the display moves continuously to the left and that the cursor frequency readout and 1/3 octave band number annotation fields decrease. When the cursor reaches the left hand limit of the display it will "wrap around" and appear at the right hand limit. Notice, also, that the cursor frequency and 1/3 octave band annotation fields change from their minimum to maximum valves when the cursor "wrap around" occurs. Place the FREQ/ORDERS switch to the ORDERS position. Repeat the above test. Note that the cursor frequency readout is now in percent of full scale, where 100 percent corresponds to the right hand edge of the display. The minimum frequency readout increment is 0.25 percent (1/400 of full scale). Restore the FREQ/ORDERS switch to the FREQ position.

Using the CURSOR CONTROL switch, move the display cursor until it coincides with the spectral line at 64 percent of the frequency axis. Notice that as the cursor crosses the spectral line, a bright dot will appear to indicate the point of intersection between the display and the cursor line. Observe the cursor amplitude readout annotation field. This field on the top line of the display is easily recognized by the units DBV. This field should read -20 DBV $\pm$2. The total rms level readout field, located directly below the cursor amplitude readout field, should read 100 -3 RMS, $\pm$21 -3.

Place the CURSOR AMPL UNITS switch into the V position. The cursor amplitude readout field should read 100 -3V $\pm$21 -3.

Place the CURSOR AMPL UNITS switch into the V2 position. The cursor amplitude readout field should indicate 10 -3V2 $\pm$4.4 -3. Return the CURSOR AMPL UNITS switch to the dB position.

Use the CURSOR CONTROL to move the display cursor to the 1000 Hz position. The cursor should be coincident with the first "tic" mark.

Place the CURSOR FREQ READING switch into the CPM position. The cursor frequency readout field on the display (upper right hand corner) should change from 1000 Hz to 60,000 cpm. Return the CURSOR FREQ READING switch to the Hz position.

Place the CURSOR FREQ TYPE switch into the HAR position. Note the appearance of eight intensified areas on the display.

The beginning of each area is coincident with a frequency axis "tic" mark. Note that the width of the intensified areas increases from the second through the sixth tic marks and thereafter remains a fixed width.

4-7. Frequency and Amplitude Scale Check

Set the FREQUENCY SCALES to the LOG position. Note that the annotation below the frequency (horizontal) axis changes from Hz to LOG Hz. The number of "tic" marks on the frequency axis should change from 10 (for the LIN scale) to 2 (for the LOG scale). Note also that the intensified areas on the frequency axis are logarithmically compressed and occupy the area between the second tic mark and the right hand edge of the display graticule.

Return the FREQUENCY SCALES switch to the LIN position, and the CURSOR FREQ TYPE switch to OFF.

4-8. Display GAIN Check

Depress the GAIN switch to the DECR position. Hold the switch in that position until the display gain annotation field (located on the left hand edge of the display) reads -50 dB. The amplitude of the displayed test signal spectrum should decrease until it is approximately five graticule divisions below full scale.

Momentarily hold the GAIN switch in the INCR position until the display gain annotation field reads -40 dB. The amplitude of the test signal should be approximately four graticule divisions below full scale (i.e. the top of the graticule).

Continue increasing the display gain in 10 dB steps until zero dB is reached. In each case, the test signal spectrum should increase by one graticule division for each 10 dB of gain.

After zero dB display gain is reached, rotate the SENSITIVITY control to the 10V (+20 dB) position. The amplitude of the test signal spectrum should be approximately 4 $\pm$2 graticule divisions below full scale.

Continue increasing the display gain in 10 dB steps until +40 dB is reached. Each increase of 10 dB in display gain will

result in the spectrum of the test signal increasing by one graticule division. Note that as the display gain is increased above zero dB, the noise floor of the analyzer will become visible. At the +40 dB display gain setting, the noise floor should be centered between the third and fourth graticule divisions below full scale (≈75 dB).

Increase the display gain to +50 dB. Note that the spectrum of the test signal intersects the top graticule line. Rotate the SENSITIVITY control to 100 MV (-20dBV). Set the AMPLITUDE SCALES switch to the LIN position. Depress and hold the GAIN switch in the DECR position until a display gain of /512 is obtained as annotated to the right of the display graticule. The spectrum of the test signal should not be visible. Momentarily place the GAIN switch in the INCR position until a display gain of /256 is obtained. The test signal spectrum should be barely visible above the lower graticule line.

Continue increasing the display gain in binary steps until a gain of X1 is obtained. Each display gain step should double the height of the test signal spectrum.

Rotate the SENSITIVITY control to the 10V (+20dBV) position. The spectrum of the test signal should be barely visible above the lower graticule line. Continue to increase the display gain until a reading of X512 is obtained. The spectrum of the test signal will double in amplitude for each display gain step. Note that with display gain of 256 and above the test signal spectrum will intersect the upper graticule line. The noise baseline will also become evident above gain settings of X8. Return the AMPLITUDE SCALES switch to the LOG position and DECR display gain until 0 dB is obtained.

4-9. Cursor Reference Set Check

Set the CURSOR FREQ TYPE switch to the SNGL position. Rotate the SENSITIVITY control to the 100 MV (-20dBV) position. Use the CURSOR CONTROL to align the display cursor with the test signal spectrum at 6400 Hz. Set the CURSOR AMPL UNITS switch in the V position. Observe and record the cursor amplitude readout. Note also that the reference field in the display annotation reads 1.00+0V/R. Depress the CURSOR AMPL REF switch momentarily into the SET R position. Upon release it will remain in the R position. Observe that the reference field of

the display annotation is now identical with the recorded value of the cursor amplitude readout. The cursor amplitude readout should read 1.00+0R and the total rms level readout should read 1.00+0 RMS.

Depress and hold the CURSOR AMPLITUDE REF switch in the SET R position. Simultaneously depress the GAIN switch into the INCR position. Observe that the reference level field of the display annotation is decreasing. The minimum range is 0.0+0 V/R. Without releasing the CURSOR AMPLITUDE REF switch hold the GAIN switch in the DECR position. Observe that the reference level annotation field is increasing. The maximum range is 999.+9 V/R. (Note that the annotation field may overflow to XXX+9.) During the time that the reference level is changing, the cursor amplitude and total RMS annotation fields will be changing in a direction opposite to the reference level. Release the CURSOR AMPL REF and GAIN switches.

4-10. DATA HOLD check

Rotate the INPUT AMPLITUDE SENSITIVITY control to the 200 MV position. Depress the AUTO ARM pushbutton. The ARMED indicator should be illuminated. Rotate the TRIG LEVEL control one position counter clockwise (+3/8). The ARMED indicator should be extinguished and the HOLD indicator should be illuminated.

Rotate the TRIG LEVEL control to the -1/2 position. Repeat the test above with the following exception; the TRIG LEVEL control should be rotated clockwise by one position (to -3/8). The result should be the same as above.

Clear the HOLD indicator by depressing the HOLD/REL pushbutton. Return the SENSITIVITY control to the 100 MV (-20dBV) position.

4-11. Average Mode and Display Check

Set the CURSOR FREQ TYPE switch to the OFF position. Depress the DISPLAY A pushbutton. Verify that the average mode annotation field (lower left hand corner of the display) reads S (for SUM MODE). Depress the SPECTRUM AVERAGE to DIFF MODE pushbutton. The average mode annotation field should read D. Similarly, the average mode annotation field should read E and P for the EXPONential and PEAK MODE respectively.

Depress the SUM MODE pushbutton again. Note the number N annotation field (located immediately below the averager mode annotation field) should read 1. Rotate the NUMBER-N control through its entire range. At each position, verify that the NUMBER-N switch and the display annotation field are identical. Restore the NUMBER-N control to the 1 position.

Depress the START A pushbutton. The IN PROCESS indicator should be momentarily illuminated. The spectrum of the test signal (a single spectral line at 6,400 Hz) should be evident.

Repeat the above test for NUMBER-N control settings of 2 through 512. In each case the resultant spectrum should be identical. The IN PROCESS indicator should flash until processing is completed. The length of time the IN PROCESS indicator flashes should double for each doubling of the NUMBER-N setting.

Rotate the NUMBER-N control to the CONT position. Depress START A, the IN PROCESS indicator should be illuminated. (In units with Serial Numbers 70-48-037 and higher, the indicator will flash.) Notice that the amplitude of the test spectrum will increase slowly. Depress the STOP A pushbutton. The IN PROCESS indicator will be extinguished and the test spectrum amplitude will remain stable. Depress the CONT A pushbutton. The IN PROCESS indicator should be illuminated again and averaging of the test spectrum will resume. Depress STOP A and rotate the NUMBER-N control to the 32 position.

4-12. Averaging Display Mode Check

Depress the START A pushbutton. Wait until the IN PROCESS indicator stops flashing. Verify the presence of the test signal spectrum at 6,400 Hz. Depress the DISPLAY B pushbutton. Ignore the display. Depress the TRANSFER A B pushbutton. The display should be identical with the test signal spectrum obtained above.

Depress the $\frac{\text{INST}}{\text{A}}$ pushbutton. The display should be similar to Figure 4-4. Rotate the SENSITIVITY control to the 10V (+20dBV) position. Observe that the upper spectrum display decreases in amplitude to approximately four divisions below full scale.

Depress the $\frac{\text{INST}}{\text{B}}$ pushbutton. The only change in the display should be the change from A to B on the display and

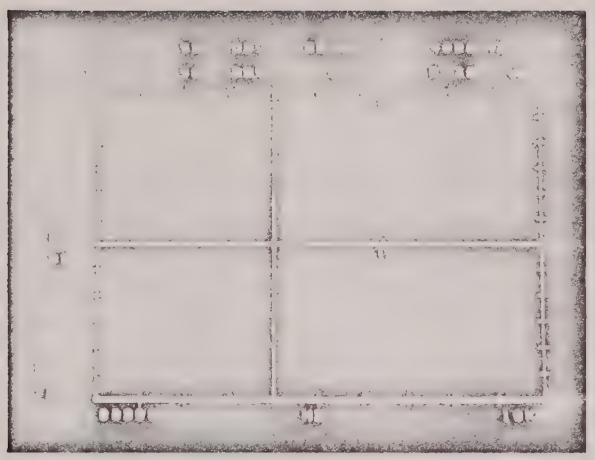


FIGURE 4-4

function annotation on the left hand edge of the display. Return the SENSITIVITY control to the 100 MV (-20dBV) position. Observe that the upper spectrum amplitude increases to nearly full scale.

Depress the $\frac{A}{B}$ pushbutton. The display should remain unchanged except for the displayed function annotation which should read A on the upper display and B on the lower.

Rotate the SENSITIVITY control to the 200 MV position. Depress the DISPLAY A pushbutton. Depress the START A and wait for processing to stop. Place the CURSOR FREQ TYPE switch into the SNGL position. Use the CURSOR CONTROL to line the vertical display cursor with the test signal spectrum at 6,400 Hz. Place the CURSOR AMPL UNITS switch in the dB position. Note the amplitude of the test signal spectrum on the cursor amplitude annotation field. Depress the TRANSFER A B pushbutton. Display the B averager memory by depressing DISPLAY B. Note that the cursor amplitude readout is the same as previously recorded. Depress the A+B pushbutton. Note that the cursor amplitude readout should increase by 3 dB (e.g., if -22 dB were originally recorded on average A, then A+B should read -19 dB).

Depress A-B, note that the test signal spectrum amplitude is attenuated. (Note that a spectral line of low amplitude

>30 dB below full scale) may be visible. This is normal. The cursor amplitude readout will be more than 30 dB below the reading obtained previously.

Depress the B-A, note a similar result. The cursor amplitude readout may be different from that obtained for A-B. A reading of -XXX indicates a zero condition. Rotate the SENSITIVITY control to the 100 MV (-20dBV) position. Depress START A and wait until processing is complete. Depress the TRANSFER A→B pushbutton. Rotate the SENSITIVITY control to the 200 MV position. Depress the START A pushbutton and wait for processing to stop. Depress the A/B pushbutton. Place the CURSOR AMPL UNITS switch to dB and the REF switch to 1V. Use the GAIN control switch to adjust the display gain to -20 dB. Use the CURSOR CONTROL to align the display cursor with the test signal spectral peak at 6,400 Hz. Note the cursor amplitude reading (it should be 0 dBV). Note that the average amplitude of the remaining spectrum points is approximately 6 dB higher than the point measured above.

Depress the B/A pushbutton. Note that the 6,400 Hz spectrum point is now an average of 6 dB higher than the remaining spectrum points. Restore the display gain to 0 dB by using the GAIN control. Depress the DISPLAY A pushbutton.

4-13. Averager Mode Check

Depress the DIFF MODE pushbutton. Depress the START A pushbutton and observe the display. Notice that the test signal spectrum slowly decreases to near zero.

Depress the EXPON MODE pushbutton. Depress the START A pushbutton. Observe that the IN PROCESS light will flash for approximately 15 seconds and then remain illuminated continuously. Rotate the SENSITIVITY control to the 100 MV (-20dBV) position. Observe that the test signal spectrum slowly increases to approximately -20 dB as read on the cursor amplitude readout. Depress the STOP A pushbutton. The IN PROCESS indicator should be extinguished.

Depress the PEAK MODE pushbutton. Rotate the SENSITIVITY control to the 10V (+20dBV) position. Set the NUMBER-N control to the CONT position. Depress the START A pushbutton. Observe that the amplitude of the spectrum of the test signal is approximately four graticule divisions below full scale. Rotate the

SENSITIVITY control to the 1V (0dBV) position. Observe that the amplitude of the test signal spectrum increases by two graticule divisions. Set the SENSITIVITY control back to the 10V (+20dBV) position. Verify that the amplitude of the test signal spectrum does not change. Depress the STOP A and the SUM MODE pushbuttons. Rotate the NUMBER-N control to the 1 position. Depress the DISPLAY INST pushbutton.

4-14. Plotter Mode Check

Rotate the INPUT AMPLITUDE SENSITIVITY to the 100 MV (-20dBV) position. Depress the PLOTTER ORIGIN pushbutton. Note the appearance of an intensified dot located at the lower left-hand corner of the graticule. Depress the PLOTTER FULL SCALE pushbutton and note that the intensified dot is now located in the upper right-hand corner of the display graticule.

Place the CURSOR FREQ TYPE switch into the OFF position. Verify that the cursor is not visible on the display. Depress the PLOTTER AT CURSor pushbutton. The cursor should appear but no cursor annotation should be evident. Depress the PLOTTER START PLOT pushbutton. Note that the cursor will disappear momentarily and then reappear at the left-hand side of the graticule moving toward the right. Notice that as the cursor intersects the spectral line at 6400 Hz, the points of intersection will be intersected. The cursor will also pause momentarily as it crosses the test signal spectral line. Depress the PLOTTER AT CURSor pushbutton.

Depress the STORE CRT pushbutton. Note that each time this button is depressed the entire display is read out slowly and is then restored to normal. The readout time for the STORE CRT mode is approximately one second. This completes the check of the PLOTTER modes.

4-15. 1/3-Octave and 1/1 Octave Mode Test (Optional)

If the Option -03 (1/3 and 1/1 octave analysis) Mode is included in your unit, proceed with this test; otherwise, continue with paragraph 4-16.

Place the CURSOR FREQ TYPE switch in the SNGL position. Depress the RESOLUTION 1/3 OCT pushbutton. Verify that the annotation below the lower graticule line indicates 1/3 octave. Verify that the spectrum display appears similar to Fig. 4-5.

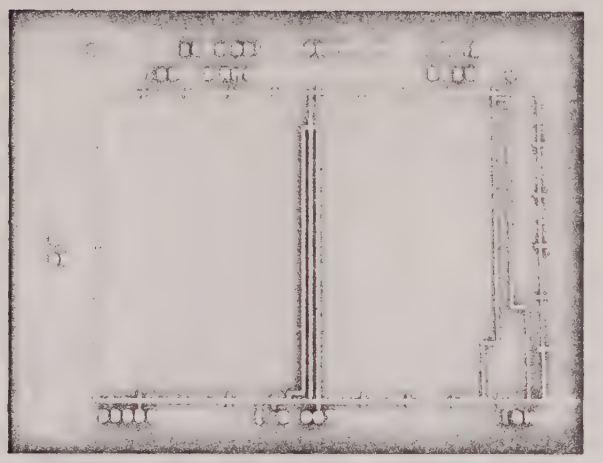


FIGURE 4-5

Notice that there are two well defined spectrum peaks at 1/3 octave band numbers 25 and 38. This can be checked by aligning the cursor with each peak and reading the band number indicated. Depress the 1/1 OCT pushbutton. Verify that the annotation below the lower graticule line reads 1/1 octave and the display appears as in Figure 4-6, below.

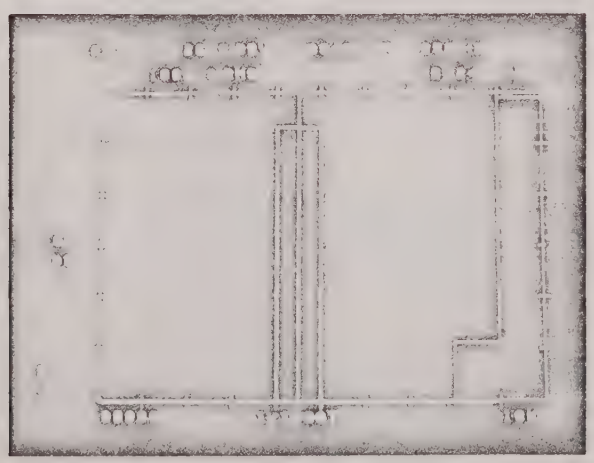


FIGURE 4-6

The two well-defined peaks in the display should appear at octave bands 24 and 39.

Depress the RESOLUTION 400 LINE pushbutton and place the CURSOR TYPE switch to the OFF position.

4-16. INPUT WEIGHTING Check

Place the CURSOR TYPE switch into the SNGL position. Using the CURSOR CONTROL, align the cursor with the spectral line at 6400 Hz. Record the amplitude of the test signal as annotated in the cursor amplitude display field. It should be -20 ±2 dBV. Place the INPUT WEIGHTING control in the A-WT position. The cursor amplitude should decrease by approximately 0.3 dB (e.g., if the original reading was 21.4 dB, the reading with the A-weighting on should be 21.7 dB).

Rotate the FREQUENCY RANGE switch to the positions indicated in Table 4-4. Verify the cursor amplitude readout is within ±2 dB of the levels shown in Table 4-4.

TABLE 4-4

FREQUENCY RANGE	Cursor Amplitude
100,000	50 dB
50,000	37 dB
20,000	25 dB
10,000	20 dB

4-17. Rear Panel Controls

Place the ANNOTATION switch into the GRAT position. Place the CURSOR TYPE switch into the OFF position. Verify that all the annotation on the display is off.

Place the ANNOTATION switch into the DATA position. Verify that the graticule disappears leaving only the spectrum display. Return the ANNOTATION switch to the FULL position.

4-18. WEIGHTING WINDOW Switch

Verify that the weighting annotation in the upper right-hand corner of the display reads W (weighted). Place the WEIGHTING WINDOW into the FLAT position. Verify that the weighting annotation now reads U. Depress the AUTO ARM push-button twice. Verify that the display looks similar to Fig. 4-7.

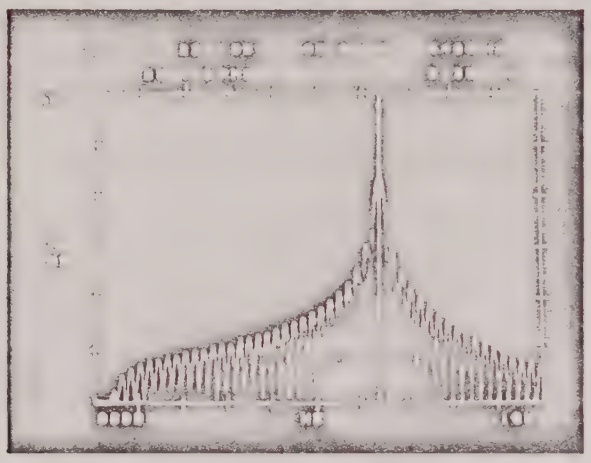


FIGURE 4-7

Place the weighting selector to HANNing. Verify that the display is similar to Fig. 4-8.

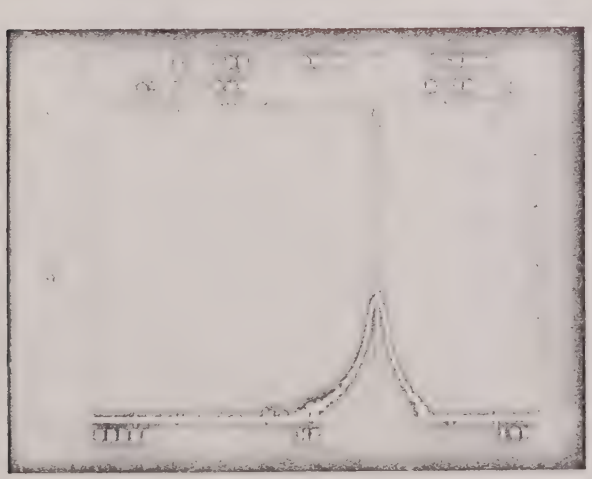


FIGURE 4-8

Place the WEIGHTING WINDOW switch in the AUTO position. Depress the HOLD pushbutton. The HOLDING indicator should be extinguished. Verify that the weighting annotation on the display reads W. Depress the AUTO ARM pushbutton. The weighting annotation should change to U. Depress the HOLD pushbutton. The HOLDING indicator should no longer be illuminated.

If the spectrum analyzer is equipped with a -2 Plug-In containing the Optional Frequency Expansion, perform the following check. If the unit does not contain this option, the operational check has been completed.

4-19. FREQUENCY EXPANSION PLUG-IN

Place the FREQUENCY EXPANSION ORIGIN switch into the INT ORIGIN position. Verify that the EXPAND ON indicator is illuminated. Set the ORIGIN FREQUENCY digital switch to the appropriate setting indicated in Table 4-5 below. Note that the bandwidth of the -2 PLUG-IN filter is annotated in the lower right-hand corner of the display when the expander is ON.

TABLE 4-5

Bandwidth of -2 Filter	Origin Frequency	Cursor Frequency
10 Hz	00000 Hz	6.4 Hz
20	00010	2.8
50	00030	2
100	00060	4
500	00300	20
1000	00600	40
2000	01200	80
10,000	06000	400
20,000	01200	800

Using the CURSOR CONTROL, align the cursor with the spectral line on the display. Verify that the frequency of these spectral lines as read on the cursor frequency annotation field match. The frequency is shown in Table 4-4, above. Place the ORIGIN selection switch into the OFF position.

This completes the check of the -2 EXPANSION PLUG-IN.

SECTION V

444 INTERFACE AND APPLICATIONS

5-1. This section of the report describes aids to understanding and efficient utilization of the Model 444 Mini-Ubiquitous® Spectrum Analyzer. Included are CRT display review, calibration procedures, set-up of analog plotters, power spectral density calibration and measurement, as well as engineering unit calibration. Also included are basic operation of the digital plotter (with 07RS232C Option) and the HP Calculator (with 07HP Option).

5-2. Review of the CRT Displays

This section will review the CRT displays and the meaning of the annotation fields.

A. Time Display (Figure 5-1)

Analyzer input signals, after passing through the input attenuator, and anti-aliasing filter are sampled and converted to digital format by an analog-to-digital converter. These digital samples are stored in a 1024 word input buffer whose contents are periodically interrogated and spectrum analyzed by the FFT processor. When a time display is requested, the 1024 word contents are displayed on the CRT display as shown in Fig. 5-1. The horizontal axis is time divided into eight segments, each representing 128 input samples. The total time is a function of the sampling rate (analysis range). (See front panel.) The vertical scale represents the input full scale range of the A/D converter. This peak-to-peak range is equal to 2.8 X the input sensitivity. Both axes are scaled linearly regardless of the AMPLITUDE/FREQUENCY LIN/LOG switches. In addition no vertical gain is allowed in this display mode and the cursor is inoperative.

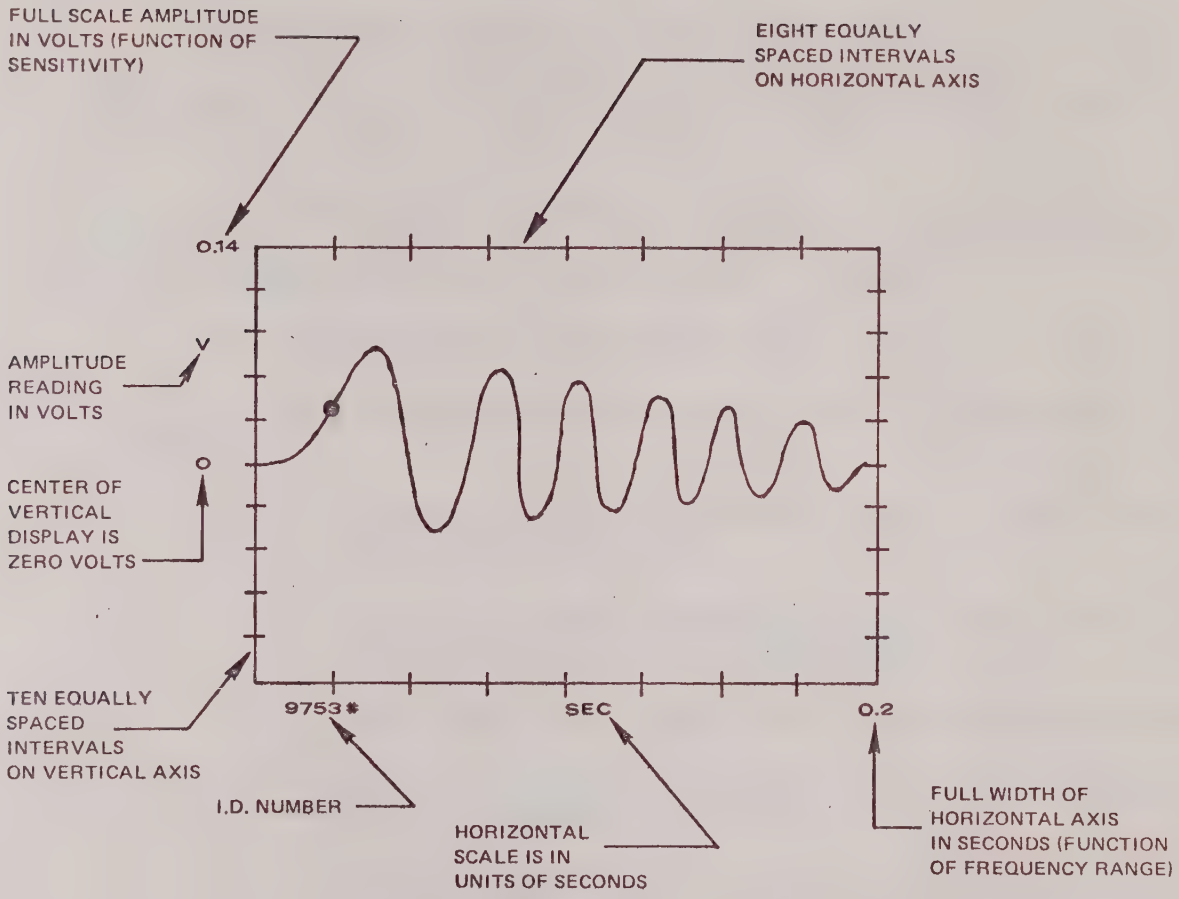

FULL SCALE AMPLITUDE IN VOLTS (FUNCTION OF SENSITIVITY)
EIGHT EQUALLY SPACED INTERVALS ON HORIZONTAL AXIS
0.14
AMPLITUDE READING IN VOLTS
V
CENTER OF VERTICAL DISPLAY IS ZERO VOLTS
O
TEN EQUALLY SPACED INTERVALS ON VERTICAL AXIS
9753*
SEC
0.2
I.D. NUMBER
HORIZONTAL SCALE IS IN UNITS OF SECONDS
FULL WIDTH OF HORIZONTAL AXIS IN SECONDS (FUNCTION OF FREQUENCY RANGE)

Figure 5-1. Time Display

Since samples are normally continuously added to the buffer, the viewing of the time display will normally be unsynchronized. (Signal will appear to slide through the display.) In the hold condition (or after transient capture) no update of the buffer takes place and the display is "frozen".

When a hold condition occurs as a result of a transient capture operation, the intensified dot at the 128 sample (1/8 total time) location corresponds to the trigger point. Both pre and post trigger signal states are visible.

The four digit ID number represents the numeric digital switch entry. The ID number represents the origin frequency of the translated band when used with the -2 option.

B. Single Spectrum Displays (Figure 5-2)

All single spectrum displays have the following in common:

1. Frequency axis represented by Hz or Log Hz and the frequency range.

2. Vertical scale gain/attenuation factor and format (linear = X or /; logarithmic = dB).

3. The input full scale sensitivity of the analyzer.

4. What spectrum is on display, such as instantaneous, averager A or B.

5. If averaged data, the type of averaging and the and the number.

6. Input A weighting (A-WT) if activated.

7. Time domain weighting - W = weighted
   U = uniform

8. ID number

In addition, if the cursor type switch is activated (single or harmonic) then the following is added to the display:

9. Total rms value of the signal in the analysis range

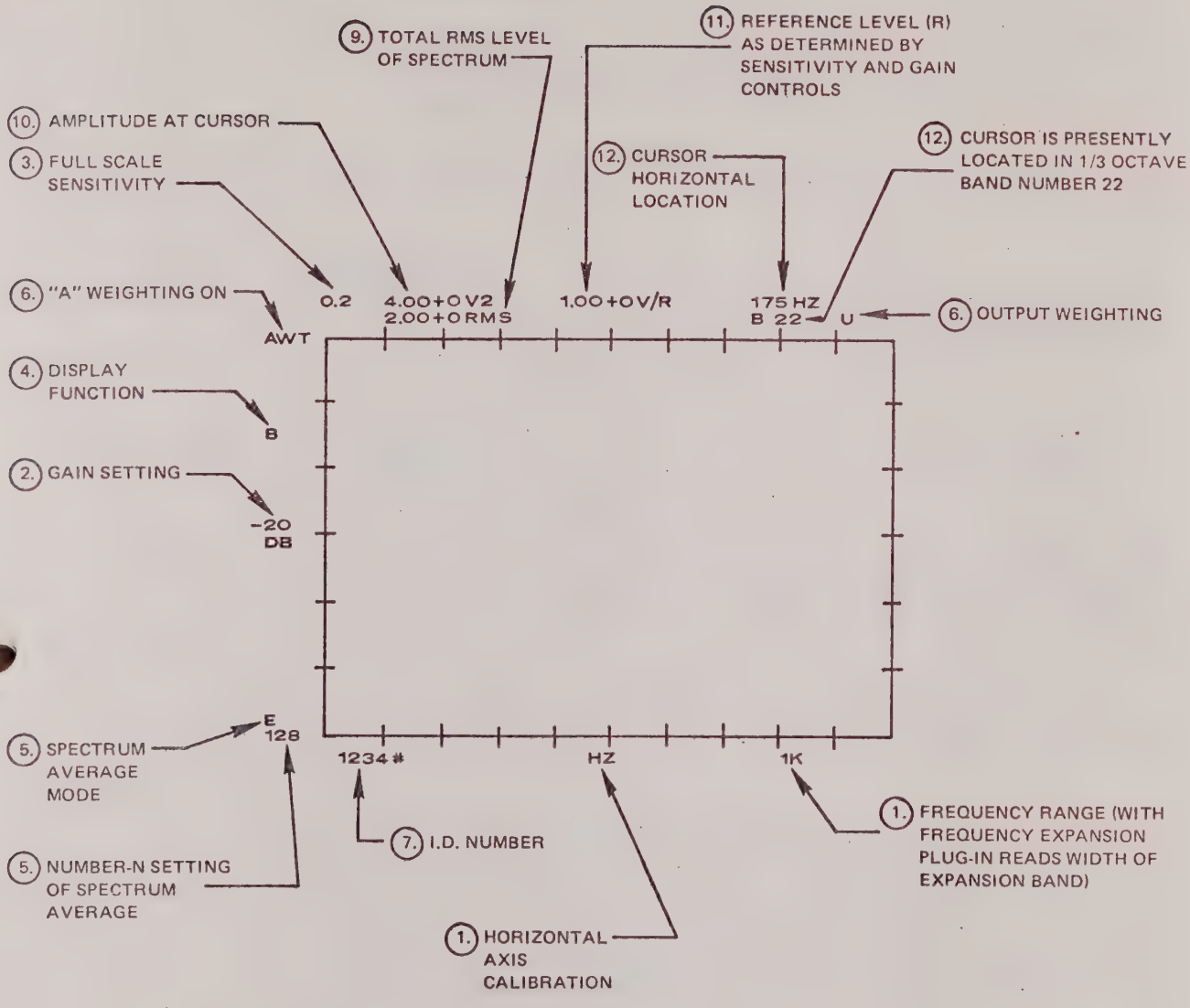


Figure 5-2. Single Spectrum Display

10. Amplitude of the signal at the cursor location in appropriate units.

11. Calibration constant V/R

12. Frequency (or CPM) of signal at cursor location as well as the equivalent 1/3 octave band number.

The top of the display (full scale) is expressed by the following:

In volts	$\frac{\text{Sensitivity}}{\text{GAIN}}$	Thus, the top of the display is equal to 1/4 volt if the sensitivity is one volt rms and the gain is X4
In volts^2	$\left(\frac{\text{Sensitivity}}{\text{GAIN}}\right)^2$	For the above example, full scale is $1/16V^2$.
In dBV	dBV - dB GAIN	If the input sensitivity is 0 dBV and the gain is +20 dB, full scale corresponds to 0 dBV - [+20 dB] = -20dBV.

It is easier however to measure signals directly with the cursor and obtain readings in V, V^2 dBV or R, R^2 or dBR. More will be presented on this topic later.

C. Dual Spectrum Displays (Figure 5-3)

Dual spectrum displays have the following:

1. Frequency axis represented by Hz or Log Hz, and the frequency range.

2. Vertical scale gain/attenuation factor and format (linear = X or /, logarithmic = dB).

3. Two full scale sensitivities; one for each spectrum displayed and representing the value of the input sensitivity of the time that spectrum was generated.

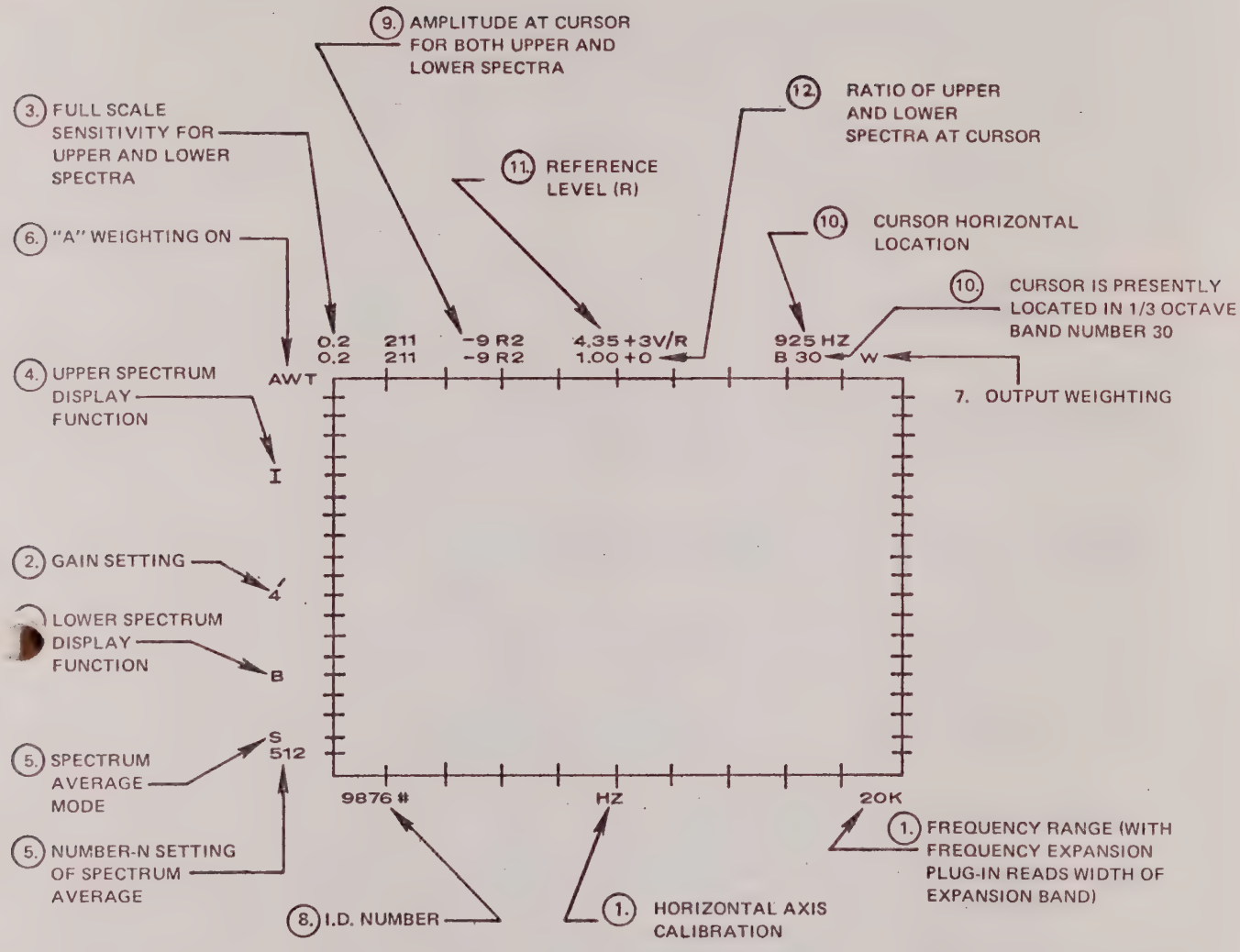

9. AMPLITUDE AT CURSOR FOR BOTH UPPER AND LOWER SPECTRA
12. RATIO OF UPPER AND LOWER SPECTRA AT CURSOR
3. FULL SCALE SENSITIVITY FOR UPPER AND LOWER SPECTRA
11. REFERENCE LEVEL (R)
6. "A" WEIGHTING ON
10. CURSOR HORIZONTAL LOCATION
10. CURSOR IS PRESENTLY LOCATED IN 1/3 OCTAVE BAND NUMBER 30
0.2 211 -9 R2 4.35+3V/R 925 HZ
0.2 211 -9 R2 1.00+0 B 30 W
AWT
7. OUTPUT WEIGHTING
4. UPPER SPECTRUM DISPLAY FUNCTION
I
2. GAIN SETTING
4
LOWER SPECTRUM DISPLAY FUNCTION
B
S
5. SPECTRUM AVERAGE MODE
512
5. NUMBER-N SETTING OF SPECTRUM AVERAGE
9876 #
HZ
20K
1. FREQUENCY RANGE (WITH FREQUENCY EXPANSION PLUG-IN READS WIDTH OF EXPANSION BAND)
8. I.D. NUMBER
1. HORIZONTAL AXIS CALIBRATION

Figure 5-3. Dual Spectrum Display

4. What spectrum is on display, such as instantaneous, averaged A or B. Upper and lower traces have their own identification.

5. If averaged data, the type of averaging and the number (of the active memory only).

6. Input A-WT if activated.

7. Time domain weighting - W = weighted
   U = uniform

8. ID number

When the cursor is activated, six additional quantities are displayed.

9. Two amplitudes, one for the upper and one for the lower trace representing spectrum amplitudes at the cursor location.

10. Two frequency readings, one in Hertz or CPM, and the other the equivalent 1/3 octave band number.

11. The engineering calibration constant volts/R

12. The ratio of the upper to lower spectrum at the cursor location.

5-3. Use of the Cursor Amplitude (Units and Ref) Switches

The two switches in the CURSOR AMPL section are very important and their use will be described in this section.

REF set to 1V - When the REF switch is set to 1V, and the cursor is activated (CURSOR FREQ TYPE equal to SINGL or HAR) the spectrum amplitude can be measured in volts, volts^2 or dBV, all referred to the input BNC terminal. When the UNITS switch is set to V, the cursor reading will be the equivalent sinusoidal rms input signal that will produce the same spectrum amplitude as that at the cursor location. When the UNITS switch is set to V^2 the equivalent volts^2 input will be displayed.

Note that in all three readings, the equivalent input signal level is displayed, and this reading is independent of display gain. It is also possible to obtain dBV readings even though the display amplitude scales are linear and vice versa.

Relative readings - Often it is desirable to make relative readings using some point on the spectrum as a reference. For this case we need two switch positions, one to tell us we want a relative reading mode and another to permit setting the reference. These are the R and Set R switch positions of the REF switch. This switch is used as follows:

1. Move the cursor to a spectrum frequency location that is to serve as the reference point.

2. Momentarily depress the switch to the SET R position (spring loaded position) and release. The switch will return to the R position and the cursor amplitude readout will be either 1R when UNITS is V
   1R2 when UNITS is V^2
   or 0DBR when UNITS is dB.
   What we have effectively done is to call the cursor location spectrum amplitude unity or 0 dB.

3. If the cursor is now moved to some other location the amplitude readout will be referenced to the reference spectrum point. For example, suppose the amplitude at the new point is 1/10 that of the reference; then the R readings would be

Units		
V	100 -3R	$= \left(\frac{1}{10} R\right)$
V^2	10 -3R2	$= \left(\frac{1}{100} R^2\right)$
dB	-20 dBR	

This is a very convenient feature since it is easy to make relative dB measurements or ratio measurements. If we call the reference one (1), then other locations are read directly in ratios (if units in V).

5-4. Calibration in Engineering Units

In many situations, it is physical engineering units which the user wants to measure, such as acceleration (g's), velocity (in/sec), displacement (mils), pressure (lbs/in), etc. A typical configuration is shown in Fig. 5-4. Here the engineering units say acceleration (g's) is converted to voltage through a transducer with sensitivity of K volts/g. To provide additional drive, perhaps a signal amplifier of gain B increases the signal level. Thus the conversion factor is KB volts/g. Suppose K = 5 mv/g and B is 20. Then KB = 100 mv/g. How can we calibrate the 444 to read directly in g's or engineering units. We can guess that we should set the calibration constant to 100 -3V/R. If you guessed, you are correct. But how do we set the V/R ratio?

1. In the CURSOR AMPL switch group, set the UNITS switch to V.

2. Hold the REF switch to the SET R position. Do not release.

3. Simultaneously move the GAIN switch to INCR or DECR. The V/R constant will change. (INCR will cause the V/R constant to decrease and DECR will cause the V/R constant to increase.) Using the GAIN switch you can single step until the correct V/R value is achieved. When the correct value has been achieved, in this case 100 -3V/R, release the GAIN switch and the SET R REF. The system is now calibrated to read directly in g's (R units). A 3g signal will read 3R (in V), $9R^2$ (in V^2) and 9.54 dBR (in dBV).

Suppose on the other hand you do not have a conversion scale constant. Instead, you have a live signal whose calibration you know; for example, a signal known to be equal to 114 dB. To calibrate the system we proceed as follows:

1. Apply this signal to the analyzer and set the input sensitivity to avoid overload.

2. Move the cursor to the spectral location.

3. Select UNITS to read dB.

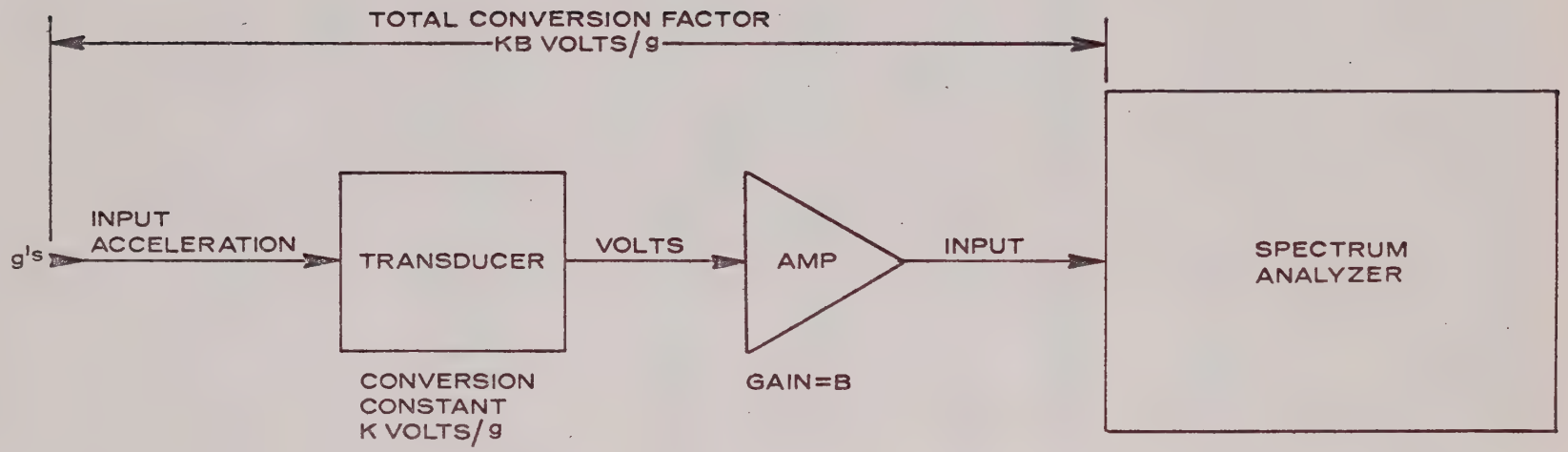


Figure 5-4. Conversion Factor Diagram

4. Hold down the REF switch in the SET Ref position and operate the GAIN switch to cause the amplitude reading to read 114 dBR. Release the REF switch. The system is now calibrated in terms of dB referenced to the live input signal.

It should be noted that we can just as easily calibrate in terms of R or R2. Thus, if the live signal were equal to 14 mils we would set the cursor reading to 14R in the V position of the UNITS switch. If it were equal to $16g^2$ we would set the cursor reading to 16R2 in the V^2 position of the UNITS switch.

5-5. Power Spectral Density Measurement and Calibration on CRT Display

By means of the V/R calibration constant, it is possible to measure power spectral density (V^2/Hz) or spectral density ($V/\sqrt{Hz}$) directly with the cursor.

In the measurement of "random" signals, whose spectral content is distributed rather then concentrated in narrow regions, it is useful to describe the spectrum in terms of a density distribution normalized to one Hertz. By so defining the spectrum, the analyzer resolution or bandwidth must be taken into account. It can be shown that the output power at a particular frequency cell in the spectrum generated by a FFT processor is equal to

$$V^2 out = V^2/Hz \times B_n, \text{ where } B_n = \text{system noise bandwidth,}$$

that is, the spectrum output is equal to the power spectral density times the noise bandwidth of the analyzer filter. For the Model 444 Analyzer the noise bandwidth is equal to

$$\frac{\text{Analysis Range}}{400} \times K$$

where: K_u = unity for uniform input weighting

K_w = 1.5 for weighted input weighting

To determine the PSD (V^2/Hz) or spectral density ($V/\sqrt{Hz}$) it is necessary to set the V/R constant to the proper value as shown in Table 1. To measure PSD directly using the cursor, proceed as follows:

1. Select the proper calibration constant for the analysis range selected and the weighting used. (Table 1.)

2. With the SET R and GAIN switch set the V/R calibration constant to be equal to the set value. For example, for the 5 kHz range and W weighting the V/R constant is 4.33. Set V/R to read 4.33+0.

3. Perform the spectrum measurement using averaged data. Since spectral density measurements are used for random data, sufficient averaging of spectrum data must be performed to generate a good (statistically stable) spectrum.

4. To read PSD set the UNITS switch to V^2. The amplitude readings (R2) correspond to PSD values (V^2/Hz).

5. Set the UNITS switch to V and the amplitude readings are spectral density $V/\sqrt{Hz}$.

6. Set the UNITS switch to dB and the reading is dB with respect to $1V/\sqrt{Hz}$.

It should be noted that because of the anti-aliasing filter ripple, the accuracy of the PSD measurements is limited to the filter ripple approximately $\pm 1/2$ dB except ± 1 dB on 100 kHz range.

To determine density in engineering units, for example g^2/Hz, multiply the V/R engineering unit constant by the set V/R number from Table 1. Thus, if we had a 100 mv/g engineering constant and we operated on 5 kHz with weighted inputs, we would reset V/R to 100 mv/g X 4.33 = 433 -3V/R. Now if the UNITS switch is set to V^2 the cursor reading will be in g^2/Hz.

TABLE 1
444 PSD Measurements Using Cursor

Range	Resolution and Uniform Noise Bandwidth B_u (Hz)	Weighted Noise Bandwidth B_n (Hz)	Set V/R to Uniform	Set V/R to Weighted
100 kHz	250	375	15.8 +0	19.36 +0
50	125	188	11.2 +0	13.7 +0
20	50	75	7.07 +0	8.66 +0
10	25	38	5.00 +0	6.12 +0
5	12.5	18.8	3.54 +0	4.33 +0
2	5	7.5	2.25 +0	2.74 +0
1	2.5	3.8	1.58 +0	1.94 +0
500 Hz	1.25	1.88	1.12 +0	1.37 +0
200	.5	.75	707 -3	866 -3
100	.25	.38	500 -3	612 -3
50	.125	.188	354 -3	433 -3
20	.05	.075	225 -3	274 -3
10	.025	.038	158 -3	194 -3
5	.0125	.0188	112 -3	137 -3
2	.005	.0075	70.7 -3	86.6 -3
1	.0025	.0038	50.0 -3	61.2 -3

5-6. Analog Plotter Interface and Calibration

This section will describe interfacing of an analog X-Y plotter to the Model 444 and its calibration.

A. Interface

To interface with an X-Y plotter, it is simply necessary to connect the X-Y TO PLOTTER outputs at the rear of the 444 to the corresponding inputs of the plotter. The pen lift can be used if the plotter is equipped with a corresponding input command. Otherwise, the pen must be manually lowered or raised in the plot mode.

B. Calibration of an X-Y Plotter without the Use of an External Calibration Signal

The object of plotting is to have a hardcopy of either the time or spectrum data on a set of axes determined by the user and the type of plotter paper available. The calibration procedure is to see that the origin and the maximum excursions in both the horizontal and vertical direction line up with proper points on the plotter paper.

To calibrate the analog plotter, the spectrum analyzer can operate in three calibration modes which can be of use to the operator. These three modes are called the PLOTTER ORIGIN, PLOTTER FULL SCALE, and PLOTTER AT CURSOR. In each mode, DC calibration signals are available as shown in Fig. 5-5.

1. PLOTTER ORIGIN - When this button (on the 444) is depressed, the analyzer feeds out two analog signals, one for the vertical and one for the horizontal, to the plotter, which defines the lower left-hand graticule location of the CRT display. These voltages are close to zero volts.

2. PLOTTER FULL SCALE - When this button is depressed, the analyzer feeds out the vertical and horizontal voltages corresponding to the upper right-hand corner of the graticule display, typically +3.2 volts.

3. PLOTTER AT CURS - If the PLOTTER AT CURSor button is depressed, the analyzer feeds out two analog signals that correspond to the vertical and horizontal deflection of the point which is intensified at the cursor location. As the

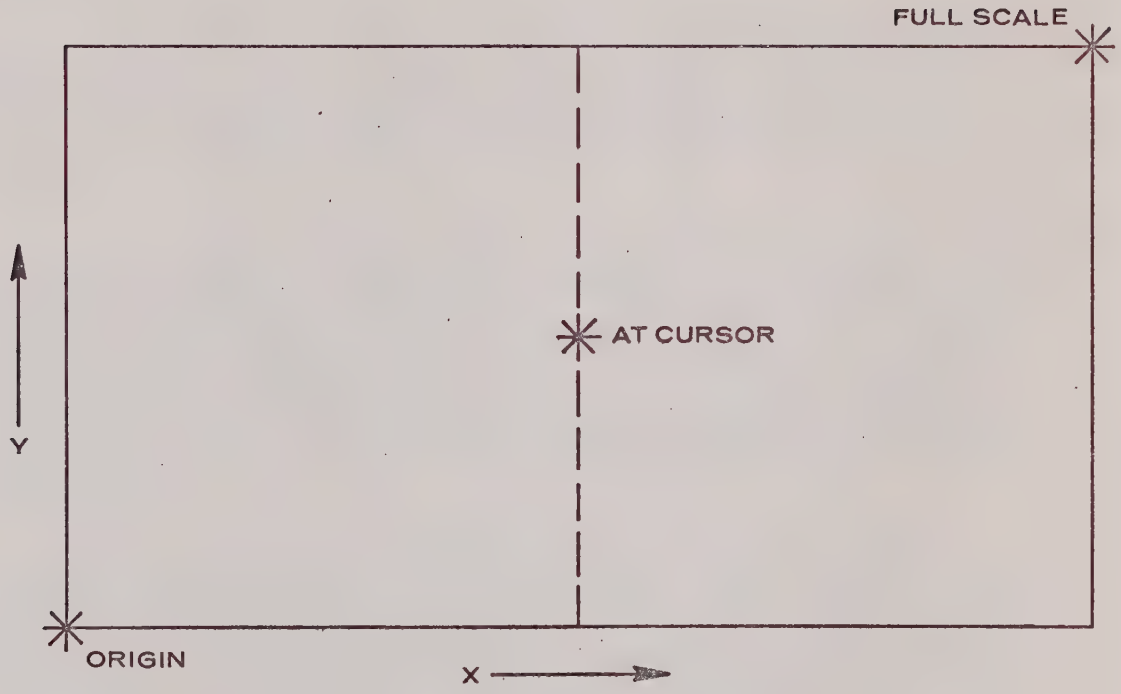


Figure 5-5. DC Level Calibration Locations

cursor location is changed, the horizontal and vertical amplitude (if a signal is present) will change. It is possible then to develop two DC voltages corresponding to a unique point on a spectrum display.

Let us now try to calibrate an analog plot in which the vertical axis is divided into five divisions and the horizontal axis is to be on a logarithmic display. How does one go about plotting a spectrum on this type of paper? Suppose the full scale sensitivity of the analyzer is set for 500 millivolts and the analysis range is 10 kHz. The way to calibrate this plot is as follows:

1. The user must define where he wants the 10 kHz frequency point to appear, and where the upper line of his display is on the paper. Having thus defined these two points, the user has in effect defined the full scale (upper-right) location.

2. The user will then locate where the lower left-hand corner is; namely, where zero amplitude and a frequency of 1/400 of full scale is located. On a log horizontal display the analyzer can present only 400 distinct points. The upper one being 10,000, the lower one being one resolution element or 10,000 divided by 400 or 25 Hz. The user then defines on his log paper where 25 Hz is, having already defined where 10 kHz was initially.

3. It is now only necessary to get the origin point of the CRT display to line up at the origin point of the plotter paper and the full scale to line up on the full scale of the paper. The way to proceed is to first press the ORIGIN button and use the X-Y offset controls of the plotter to locate the orign point. Then press PLOTTER FULL SCALE and adjust the vertical and horizontal gain controls on the plotter until the pen is at the full scale location. It will be necessary to go back and forth between the plotter origin and plotter full scale positions until the plot lines up correctly with those two end points, each time making slight gain and offset adjustments.

4. To make sure that the log horizontal axis is properly calibrated, it is possible to use the plotter at cursor mode. Press the PLOTTER AT CURSor button and set the cursor to the 1000 Hz resolution element. The pen should now

move to the 1000 Hz location on the horizontal frequency axis. The amplitude would correspond to the amplitude that is on the display which may not be defined at this moment. It is thus possible to use the AT CURSor location for frequency axis calibration at any time. The vertical amplitude will be used at a later time when we discuss calibration with an external calibration signal.

The procedure just outlined permits one to transfer a spectrum or time, CRT display onto pre-printed (or defined) analog plotter paper. The procedures would be the same using a log amplitude or a log linear horizontal axis or combinations of the two. The full scale value of the plotter is related to input sensitivity and gain settings as shown by lines 1, 2, 3 of Table 2.

C. Calibration in Engineering Units without an External Calibration Signal

The above procedure describes how to calibrate a plotter in terms of voltages. However, if it turns out that a scale constant is available to convert from voltage to engineering units, it is possible to calibrate the analog plot in terms of engineering units. Using the above example, suppose that the scale factor were 120 millivolts/g. The first thing we know is that since the full scale sensitivity is 500 millivolts, the full scale display in g's would be equal to 500 divided by 120 millivolts or 4.17 g divided by the gain factor. Assume the gain is 1. Unfortunately, the paper was divided into five vertical lines and making the top or 5th line 4.17 g would make each of the other lines an oddball reading. Therefore, what we would like to do is to let the 5th line correspond to 5 g. Therefore, when we press the full scale button we should line up the vertical axis to correspond to 4.17 divisions on the paper. Similarly, when we press the PLOTTER ORIGIN button, the vertical amplitude will be zero and the frequency will correspond again as before to 25 Hz. In setting up the output display in this way we find that each of the major divisions of the plotter paper corresponds to 1 g and the plot is calibrated in terms of engineering units without the use of an external calibration signal. Table 2, lines 4, 5, 6 indicate full scale settings in engineering units given the V/R factor.

TABLE 2
Full Scale Display Readings

1.	In Vrms	$\frac{\text{Sensitivity}}{\text{GAIN}}$	i.e. $\frac{2V}{4}$ = 1/2 Vrms
2.	In $Vrms^2$	$\left(\frac{\text{Sensitivity}}{\text{GAIN}}\right)^2$	i.e. $\left(\frac{2V}{4}\right)^2$ = 1/4 $Vrms^2$
3.	In dBV	dBV- GAIN	i.e. +6dBV- +20 = -14dBV = 200 mV
4.	In R	$\frac{\text{Sensitivity}}{(V/R) \cdot (\text{GAIN})}$	i.e. $\frac{500mV}{120mV/Rx1}$ = 4.17R
5.	In R^2	$\left(\frac{\text{Sensitivity}}{(V/R) \cdot (\text{GAIN})}\right)^2$	i.e. $\left(\frac{500mV}{120mV/Rx1}\right)^2$ = 17.39R^2
6.	In dBR	dBV- GAIN -20 $\log_{10}$ V/R	i.e. -6dB - 0 -[-18.42] = +12.42 dBR (4.17R)
7.	In V^2/Hz	Reading 2 divided by B_n	
8.	In R^2/Hz	Reading 5 divided by B_n	
9.	In dB(V/$\sqrt{}$Hz)	Subtract 10 $\log_{10}$ B_n from 3	
10.	In dB(R/$\sqrt{}$Hz)	Subtract 10 $\log_{10}$ B_n from 6	

B_n = Noise Bandwidth of Analyzer Filter

D. Some Other Calibrations

Other calibrations possible are:

PSD - Table 3 presents the full scale PSD and spectral density values for all analysis ranges and 1Vrms sensitivity. The general full scale value is:

$$\text{Full Scale PSD (Table 3)} \times \text{Sensitivity}^2 \times \frac{1}{(\text{GAIN})^2} = \text{PSD}_{V^2/\text{Hz}}$$

$$\text{Full Scale Spectral Density (Table 3)} \times \text{Sensitivity} \times \frac{1}{\text{GAIN}}$$

$$= \text{Spectral Density } V/\sqrt{\text{Hz}}$$

Density displays are generally displayed on logarithmic amplitude scales. Similar to the engineering calibration we would like to keep the vertical scale paper divisions nice-reading numbers. Therefore, in using six decade (60 dB) paper, we would line up the full scale value calculated above to the appropriate division. For example, with a gain of two, weighted and 200mV rms input sensitivity on 5 kHz, the full scale PSD value is $5.3 \times 10^{-2}\ V^2/\text{Hz}$. Therefore line up the full scale vertical pen position to the 5.3×10^{-2} line on the paper. The origin corresponds to 5.3×10^{-2} -60 dB = $5.3 \times 10^{-8} V^2/\text{Hz}$.

PSD in Engineering Units - Can we calibrate our plotter in terms of engineering unit density scales? Yes. Since we know the full scale value in terms of V^2/Hz or $V/\sqrt{\text{Hz}}$ we must divide these values by $(V/R)^2$ and (V/R) respectively to get full scale R^2/Hz and $R/\sqrt{\text{Hz}}$ values. Calibration would proceed as above.

E. Calibration of an X-Y Plotter Using an External Calibration Signal

The vertical axis of a plot can be calibrated by means of an external calibration signal. The horizontal frequency axis is still determined by the internal calibration of the analyzer. Therefore, the technique used for calibrating an X-Y plotter is to first calibrate the upper and lower frequency points using the origin and full scale signals from the analyzer. Having adjusted the horizontal gain and offset control properly, the vertical amplitude is adjusted by means of the external calibration signal.

TABLE 3
Full Scale Power Spectral and Spectral Density Values
(Based on 1Vrms Input Sensitivity)

Frequency	Unweighted		Weighted	
	$V/\sqrt{Hz}$	V^2/Hz	$V/\sqrt{Hz}$	V^2/Hz
100 kHz	6.32 -2	40.0 -4	5.17 -2	26.7 -4
50	8.94 -2	80.0 -4	7.3 -2	53.3 -4
20	1.41 -1	2.0 -2	1.03 -1	1.06 -2
10	2 -1	4.0 -2	1.63 -1	2.67 -2
5	2.83 -1	8.0 -2	2.3 -1	5.33 -2
2	4.47 -1	20 -2	3.26 -1	10.6 -2
1	6.32 -1	40 -2	5.17 -1	26.7 -2
500 Hz	8.94 -1	80 -2	7.3 -1	53.3 -2
200	1.41 +0	2 +0	1.03 +0	1.06 +0
100	2 +0	4 +0	1.63 +0	2.67 +0
50	2.83 +0	8 +0	2.3 +0	5.33 +0
20	4.47 +0	20 +0	3.26 +0	10.6 +0
10	6.32 +0	40 +0	5.17 +0	26.7 +0
5	8.94 +0	80 +0	7.3 +0	53.3 +0
2	14.14 +0	200 +0	10.3 +0	106 +0
1	+0	400 +0	16.3 +0	267 +0

When using an external calibration signal, the operator knows that the vertical amplitude of this signal corresponds to either some voltage or engineering unit or some power spectral density. What we want to do in calibrating the plotter using this signal is to have the vertical amplitude scale correspond to that which the operator would like to set up on the paper.

Let us, for example, assume that an input signal is available whose amplitude is 14.6 g. The operator would select the appropriate analysis range and input sensitivity so that this signal will appear as a spectrum line without distortion. Perhaps some averaging would be desirable in case the amplitude of the signal varies slightly. The operator would then place the cursor at the peak of that calibration signal and press the PLOTTER AT CURSor switch. The plotter vertical deflection will then correspond to the 14.6 g calibration signal. The operator would then set the pen to read approximately 14.6 g on his scale. If he presses the PLOTTER ORIGIN button, the vertical displacement would go to zero. Flipping back and forth between PLOTTER ORIGIN and PLOTTER AT CURSor it is possible to get a vertical paper deflection corresponding to zero and 14.6 g, respectively. The plotter is now calibrated directly in g's. Similarly, if it turned out the sinusoidal signal were calibrated in g^2 or other quantities, this same procedure could occur.

If the vertical scale is logarithmic, then we would like to have a major vertical division correspond to so many dB. In this situation what we do is put the cursor at the peak of the signal and vary the signal amplitude by 20 dB by means of the display GAIN control. The deflection of the plotter pen corresponds then to 20 dB. If the operator has selected a certain vertical distance to correspond to 20 dB, then by means of the vertical gain and offset control the operator should be able to get the correct deflection on paper when the display gain is changed by 20 dB.

Suppose now that the full scale input of that calibration signal corresponds to 94 dB. Having adjusted the vertical displacement gain control to give a 20 dB deflection when the display gain changes by 20 dB, it is necessary to use the vertical offset control to move the pen to a position which corresponds to 94 dB on the vertical scale. If the operator

had selected six divisions, each division corresponding to 20 dB, then the top scale could be marked 120, the bottom 0 dB. The calibration signal which corresponds to 94 dB would be made to line up with a 94 dB mark on the vertical scale of the paper.

Thus, it is possible to calibrate vertical axis either without a calibration signal based on the input sensitivity of the spectrum analyzer as presented in the earlier section, or it can be set up using a live signal of known amplitude using the PLOTTER AT CURSor controls.

5-7. Operation With Tektronix 4662 Digital Plotter (07 RS232 Option)

When the Model 444 includes the 07RS232 Option, software routines are included in the analyzer permitting fully annotated plots to be produced on a Tektronix 4662 plotter.

A. Interfacing

The user must interconnect the two units as shown in Fig. 5-6. This hookup involves the following:

1. Interconnect the Model 444 and Tektronix plotter with a standard RS232 cable.

2. Set the A, B, C, D switches at rear of 4662 plotter to 7222, respectively.

3. Set the baud rate of the 444 analyzer to 600. This is accomplished by setting switch E33 on the encoder board to position 6. To gain access, remove the right side cover. The switch is located on the top front side of the encoder in column 33.

4. Set E34 to the zero position (adjacent to E33).

5. Set rear panel mode switch (on the 444) to PLOT position.

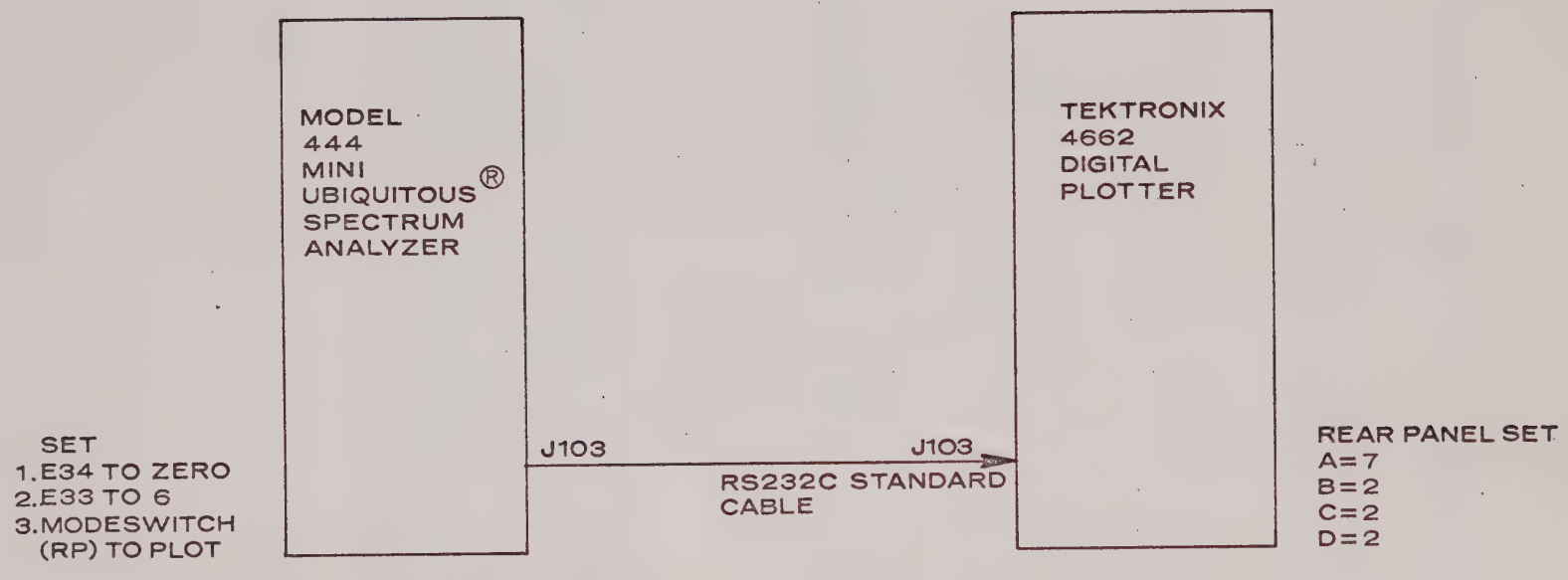


Figure 5-6. Digital Plotter Interface

B. Operation

Set up the correct size plot using the plotter controls. Typical operation would be as follows:

1. To load paper, depress the LOAD button. This releases the paper hold-down. Place the paper onto the plotter bed and align with the bottom and left edges. Release the LOAD button.

2. Set the local switch to LOCAL (depressed).

3. Determine size and location of plot as follows:

a. Using cursor, move pen to where lower left of plot should be. Press the SET LOWER LEFT button until a beep is heard. Move cursor to upper right side of the plot area. Press SET UPPER RIGHT button until beep is heard.

b. Verify proper location of plot area by pressing LOCATE LOWER LEFT and UPPER RIGHT buttons alternately. These buttons cause the pen to be located at the SET positions.

4. Release the LOCAL button.

5. Plotter is ready to plot.

6. Press the STORE CRT button on the Model 444. A plot will automatically be plotted with all the information presented on the CRT display. When the plot is completed, the pen will be in an up position and located where the last vector was drawn. To remove the paper, press LOCAL and LOAD. The former keeps the 4662 under local operator control and the LOAD causes the pen to be moved to the upper right position of the plotter bed, (out of the way) and releases the electrostatic paper hold-down.

5-8. Operation With a HP 9825A Calculator (07 HP Option)

To interface the Model 444 to a HP 9825A calculator requires the following:

A. HP 9825A calculator with the following:

1. HP 98213A "General I/O-Extended I/O"

2. HP 98210A "String-Advanced Programming"

3. HP OPT 001 "15,038 total bytes memory" (recommended)

4. HP 98032A Cable/Logic

B. Model 444 with 07 HP Option

C. Item 4 above, wired and provided with mating connectors to plug into J101 and J102 of analyzer

The interface requires 20 basic signal lines between the calculator and analyzer; these are:

1. 8-bit input (to analyzer bus)

2. 8-bit output (from analyzer bus)

3. HP control (444 $\overline{\text{XFLG4}}$ line)

4. HP Flag (444 $\overline{\text{XCTRL}}$ line)

5. HP directional control line (tied to XD 19 line of analyzer) to generate 6/7 or 14/15 code. See interface notes).

6. Ground

When the two units are interfaced as described, it is possible to send byte data to the analyzer. This data can be used to establish control settings, load time data into the input buffer, or instruct the Model 444 to send data to the calculator. The software driver package is the responsibility of the user.

SECTION VI

MODEL 444 BLOCK DIAGRAM DESCRIPTION

6-1. Scope of This Section

This section will present a block diagram description of the 444 system and will provide a breakdown of each block with regard to its function and physical board location.

6-2. Organization of the 444

The 444 is organized so that the input plug-in unit performs all the necessary analog signal conditioning and digitizing of the input signal prior to actual system processing. Six small printed circuit boards comprise the basic plug-in unit and these boards will be described in further detail below. The -20 plug-in makes use of the same six boards, but has an additional three boards which are described in Section VIII of the manual. These boards contain the expander circuits.

Digital signal processing, display control, and front panel interfacing is performed on three large wire-wrap boards located in the mainframe of the 444. The digital signal processing section accepts its input data from the plug-in unit's analog-to-digital converter and provides two output buses, i.e., the horizontal and vertical buses, as well as Z-axis and mode control signals to the system's display board.

The function of the system display is to convert the digital bus signals into corresponding analog signals to drive the corresponding deflection plates of the system display CRT. In addition, the display system, under the processor's control will gate the display on or off, and will scale deflection voltages according to mode commands received. The display system also provides the system's pen output, and buffered horizontal and vertical outputs.

6-3. Basic Block Diagram Description (Figure 6-1)

Data applied to the system's input is attenuated under operator control, lowpass filtered so that its frequency response

cuts off sharply at the band edge selected by the FREQUENCY RANGE control, and then digitized in the analog-to-digital converter. Each digitized input sample is placed into a successive location in the 1024 word input buffer. Note that unless the system is placed into a HOLD mode, or sampling is interrupted, this process is a continuous one. Consequently, every new input sample will overwrite, or replace, the input sample that was collected 1024 sampling intervals earlier. Input data collection is virtually independent of system control.

A block indicated in Figure 6-1 as MULTIPLEXER shows four inputs and one output. One of these inputs is the data output from the input buffer. Another input is the output bus from the system's microprocessor. The two other inputs are provided by the output from the system's active memory bank and a remote source, respectively. Although shown as a single input line, it is important to remember that each of the lines represent one or more buses.

The block indicated as MICROPROCESSOR actually consists of a number of separate block functions, which will be described in greater detail. At this point, however, it is important to realize that the MICROPROCESSOR is the controlling element of the 444 system. The MICROPROCESSOR is programmed to sequence through a predetermined number of steps, at each step performing either a group of control functions, arithmetic computations, or data manipulations, or combinations of these operations.

The MICROPROCESSOR determines which input bus to the MULTIPLEXER will appear at its output and whether that bus will be entered into one of its random memory locations or undergo logic or arithmetic manipulation with any of the MICROPROCESSOR'S internal buses.

The sequence of steps through which the MICROPROCESSOR progresses is dictated by a program stored within the MICROPROCESSOR itself. After the MICROPROCESSOR has sequenced through the required number of steps, the original data block of 1024 data samples will have undergone transformation from the time to the frequency domain.

Further data manipulation by the MICROPROCESSOR averages spectra and stores the averaged spectrum in one of its internal active memory banks.

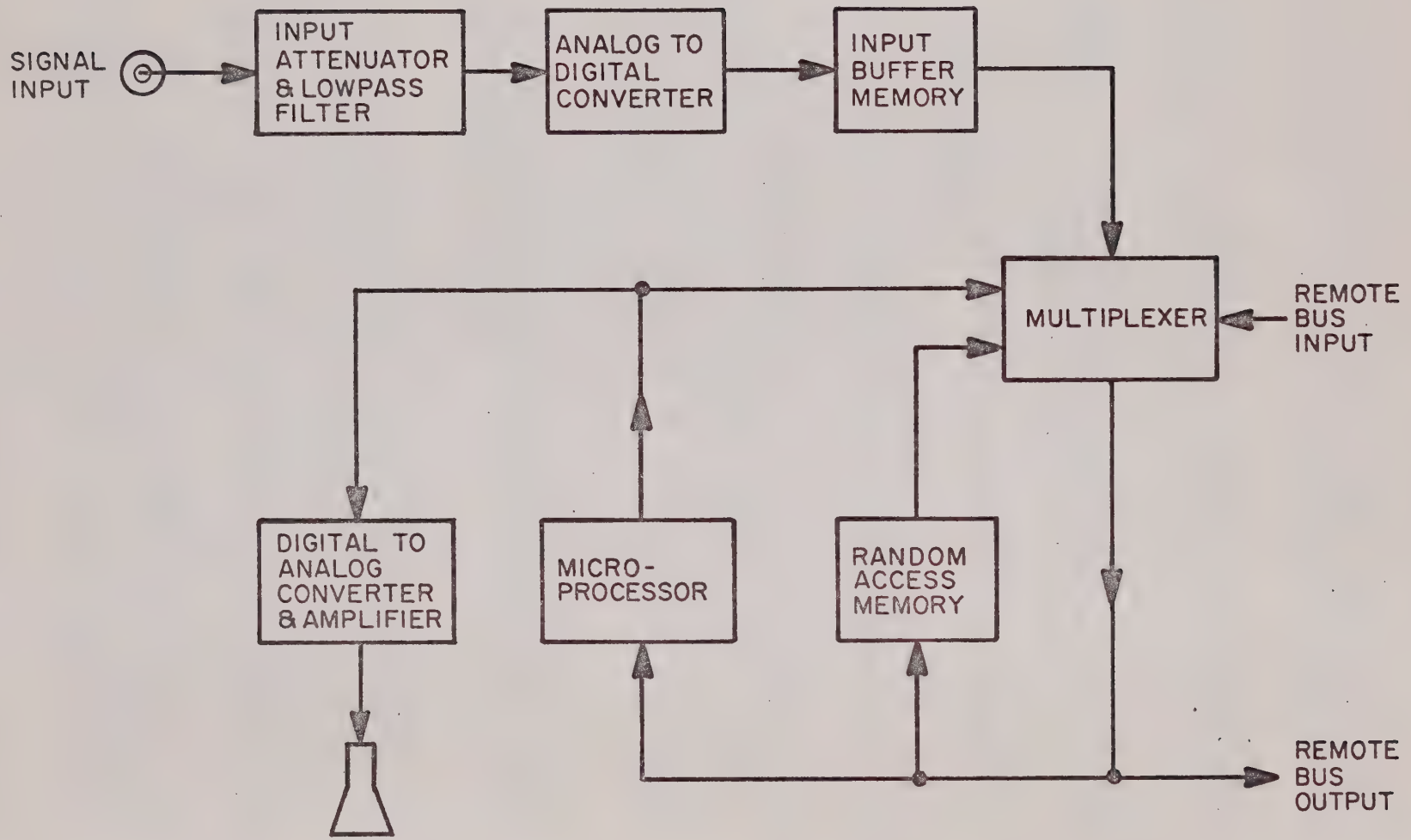


FIGURE 6-1. BASIC BLOCK DIAGRAM

The MICROPROCESSOR interrupts processing on a periodic basis to refresh the display with the most recent data to be presented, as well as to redraw the graticule and various annotation data.

Almost all front panel controls are read by the MICROPROCESSOR and echoed back to the appropriate point in the system where they are to be used.

Input and output interface control is exercised by the MICROPROCESSOR and communicated via the input and output buses available at the rear panel connectors of the unit.

6-4. Plug-In Board Description and System Block Diagram (Figure 6-2)

A. The following discussion will describe the -10 plug-in boards in detail and their function within the system. (The numbers correspond to the numbers in Figure 6-2.)

1. INPUT ATTENUATOR - The inputs to this board are the INPUT SIGNAL from the front panel INPUT SIGNAL BNC or the TEST SIGNAL generated on the SAMPLING CONTROL board. Under front panel control, one of these signals is selected and applied to a compensated step attenuator network, controlled by SENSITIVITY control on the front panel. The output of this network is then buffered and amplified.

The INPUT ATTENUATOR board also contains the shaping circuit required for the ORDER CONTROL SAMPLING INPUT signal so that a wide range of input levels and waveforms can be accommodated for external sampling.

2 and 3. FILTER NO. 1 - FILTER NO. 2 - These two boards accept the output signal from the INPUT ATTENUATOR and pass the signal through a buffer stage, a 10-stage 7-pole, elliptic, active filter, and a final gain and offset stage. All passive components used in these stages to determine frequency characteristics of the filter, are controlled by the FREQUENCY RANGE controls, or when remotely controlled by external commands.

4. A/D CONVERTER - This board receives the lowpass filtered signal from FILTER 2 board, samples and holds the signal at the sampling clock rate, performs a successive approximation of the sampled signal, and provides a parallel 12-bit digital

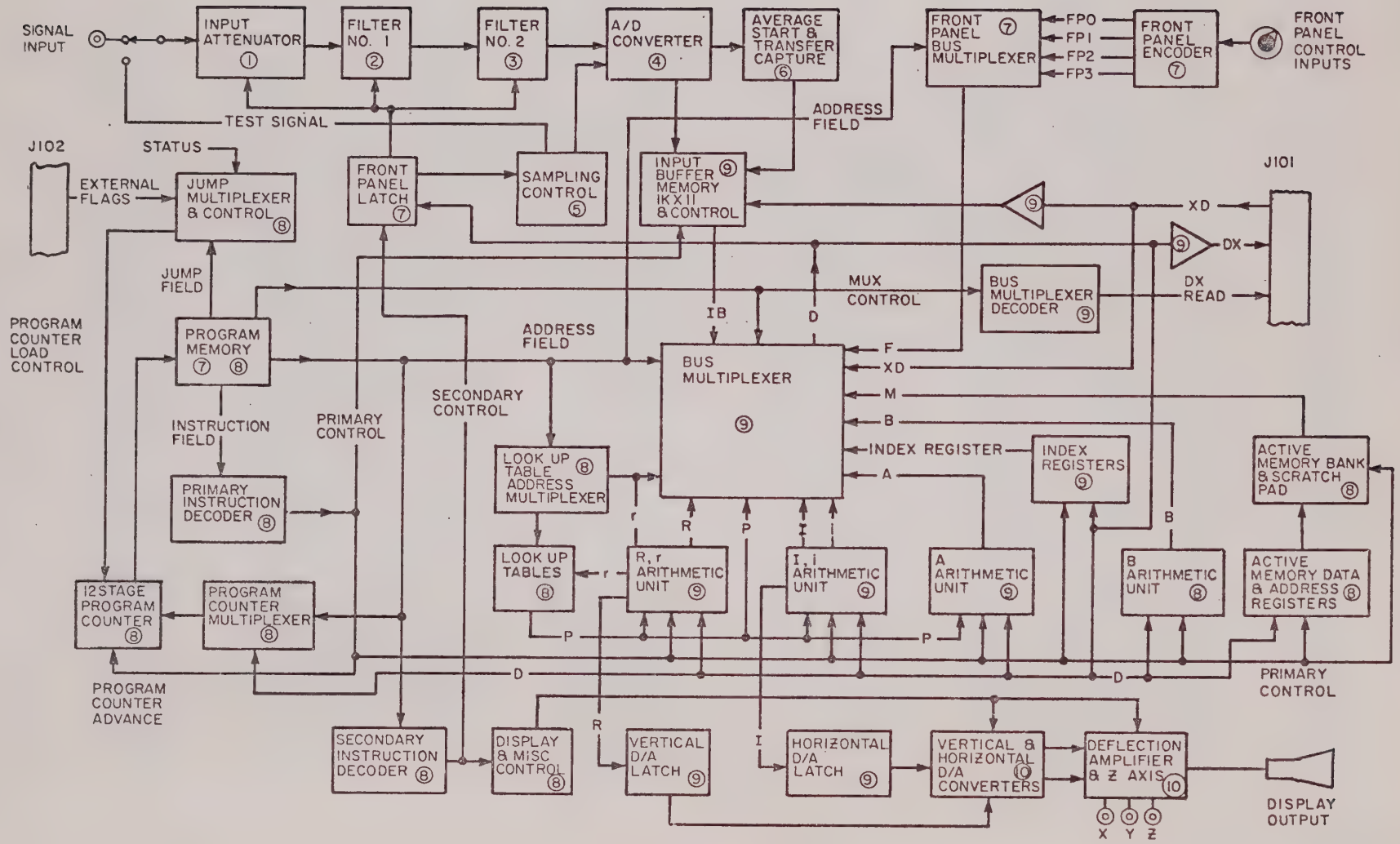


FIGURE 6-2. SYSTEM BLOCK DIAGRAM

word at the end of each analog-to-digital conversion cycle. This bus is tri-stated with the external input bus and directly applied to the input buffer.

5. SAMPLING CONTROL - This board contains the crystal oscillator and countdown circuits which generate the internal sampling frequency pulses required for the various frequency ranges selectable at the front panel. The system Test Signal is also generated on this board. This signal has a fundamental frequency equal to 64 percent of the selected FREQUENCY RANGE and will appear at 64 percent of the sweep when the internal sampling mode of operation is selected. A two millisecond clock signal is also provided by this board to the system which is subsequently counted down to the real time clock frequency of the 444 system.

6. AVERAGER START and TRANSIENT CAPTURE - The functions of this board are to generate gated end-of-conversion pulses to the write control portion of the system, to generate averager enable flags based on the input data blocks, and to regulate the HOLD operation through either manual control, or signal threshold crossing when the system has been placed in the ARMED position.

Averager start pulses are generated when either a full block of 1024 words have been entered into the input buffer memory in the external block sync mode, or whenever 512 words have been collected in the continuous sampling mode. The 512 word, 50 percent redundancy mode, permits faster averaging at the expense of some data overlap.

Digital data processed by the system is derived from either an external source or an internal source. Gated end-of-conversion pulses are derived from the delayed internal or external sampling clock. These pulses may be gated off in either of these modes whenever a full block of 1024 words are collected, if the control signal STOP ON FULL is activated in the low state. End-of-conversion pulses are also gated off whenever the HOLD is activated or whenever the system has been ARMED and the signal threshold commanded by the TRIG LEVEL control is exceeded.

The block sync pulses accepted by this board and the status flip-flop BUFFER FULL serve to delineate blocks of 1024 words when used in conjunction with an external data source and external end-of-conversion pulses.

Other output signals from this board include the drive signals for the front panel: ARMED, HOLDING, OVERLOAD, and AMPLITUDE indicators.

6-5. Mainframe Board Description and System Block Diagram (Figure 6-2)

A. The following discussion will describe the functions and interactions of the three large system boards with respect to the presentation of the block diagram in Figure 6-2.

7. ENCODER - This board contains the interface between the front panel and the system Microprocessor. Front panel switch contacts are encoded and assembled into four processor words. At any point in the program, a secondary instruction may be issued which will select one of these four data words and permit it to appear at the output of the Bus Multiplexer. In this manner, the Microprocessor is able to read the entire front panel status in a sequence of four secondary instructions. The meaning of the term "secondary instruction" will be explained below.

The Microprocessor echoes front panel settings back to the corresponding control circuits, where necessary, by placing the matching data word on the common "D" bus through one of the other inputs to the Bus Multiplexer. Again, under secondary instruction control, the "D" bus is clocked into the front panel latch which in turn exercises control over such operations as INPUT SENSITIVITY, TEST/INPUT SIGNAL, FREQUENCY RANGE, and FREQ/ORDERS. If the 444 is commanded to control the lower front panel from a remote source, the "D" bus that is returned by the Microprocessor into the front panel latch will reflect a command that was applied by the remote source on the external input bus, and will not be an echo of the corresponding front panel bus.

The ENCODER also includes special debouncing and synchronizing circuits for front panel switch contacts, where required. In addition, the system's Program Memory is located on the ENCODER and this block will be described in conjunction with the PROGRAM CONTROL board below.

8. PROGRAM CONTROL - This PROGRAM CONTROL board includes the Program Counter, Primary and Secondary Instruction Decoders, Jump Multiplexer, Random Access Memory Banks and Data Registers, Look-Up Tables, and the "B" Arithmetic Unit. These units will now be explained:

a. Program Counter - The Program Counter determines the sequence of instructions that are executed in the system by generating sequential instruction addresses to the Program Memory. The counter can either step by an increment of one, which occurs when no special jump decision is made by the program, or can be loaded with a value determined by the current instruction itself. This value may be either a "literal" value, i.e., one that is directly derived from a portion of the instruction word, or from the system "D" bus. Recall that this is the common output bus from the Bus Multiplexer. The selection of input bus to appear at the output of the multiplexer is, of course, also executed by the current instruction word.

b. Program Memory - The Program Memory consists of groups of ROM's (Read Only Memories) which are addressed by the Program Counter to provide the instruction words that sequence the 444 system through its operations. Each instruction word is broken into eight fields, as follows:

Four fields are used to provide four independent instructions to four groups of arithmetic units within the system.

One field is used to independently address the system's "scratch pad" memory.

One field is coded to activate the jump operation upon detection of a system status assigned to that code.

One field is coded to select one input bus to the Bus Multiplexer to appear at the multiplexer output, i.e., the "D" bus.

The eighth field contains the address to be loaded into the Program Counter upon detection of a jump status condition. If an unconditional "no jump" is commanded, this field is used to address various Look-Up Tables used by the 444 system. If the "no jump" command condition is true, and only a limited portion of this field is needed for a Look-Up Table, then the remaining portion of this field is used as a set of secondary instruction codes.

c. Primary Instruction Decoder - The four fields containing four separate instruction words to the various arithmetic units within the Microprocessor portion of the system are binary coded for maximum efficiency. To translate these coded instruction words into corresponding hardware control signals, the Primary Instruction Decoder is used. Note that the four fields comprise the primary instruction portion of the entire word because these fields are dedicated to arithmetic instruction and multi-control. In contrast, the secondary instruction portion of the entire instruction word is shared with the address function of the same field, and generally yields only a single control function at any given time.

d. Secondary Instruction Decoder - This block of hardware decodes the secondary instruction portion of the address field (the eighth field described above) and generates a unique control function for any given code. As noted above, secondary instructions are inactive if a jump condition is tested or if the full address field is dedicated to a lookup operation.

e. Look-Up Tables - These tables contain all the necessary constants and conversions, e.g., logarithms and anti-logarithms, as well as alpha-numeric coded character images, for reference by the main program.

f. Look-Up Address Multiplexer - The Look-Up Tables may be addressed directly by the address field of the instruction word or by a specific system register output (the "r" bus shown in the block diagram) such as would be required when the address is data dependent. The Look-Up Address Multiplexer selects the appropriate bus and this selection in turn is controlled by the high order bits of the address field.

g. "B" Arithmetic Unit - This arithmetic unit is configured to efficiently implement address manipulation used in the processing algorithms of the Fast Fourier Transform.

h. Display and Miscellaneous Control - This hardware includes all the Microprocessor I/O controls to the Display section of the 444 system, e.g., logarithmic scale, plot mode, intensity axis gate, as well as certain controls used by the Microprocessor itself. The latter includes the acknowledgment of the real time clock, program flags, reset of hardware flags, control of the front panel IN PROCESS indicator, and

loading of the Front Panel Latch. Also included in this block are various controls required for the operation of output devices, such as the Tektronix 613 Storage Oscilloscope. Note that the inputs to this block are the outputs from the Secondary Instruction Decoder.

i. Active Memory, Data and Address Registers - These registers contain the data and the address values to be used in conjunction with a selected memory from the active memory bank. The inputs to both these registers are provided by the system "D" bus.

j. Active Memory Bank and Scratch Pad - The active memory is made up of three memory groups:

(1) Processor Memory
(2) Averager Memories
(3) Display Buffer

The Processor Memory stores the input array of sampled data and successive transformations of this data into an array of frequency elements. The complex spectrum is derived from this memory after the final transformation process.

The Averager Memories store the accumulated values of successive power spectra when the averaging mode is enabled. The method of accumulation is, of course, determined by the front panel SPECTRUM AVERAGE mode controls.

The Display Buffer is used to store the 400 spectral values appearing on a frequency display. Note that time data passes directly from the input buffer to the display and does not get buffered in the Display Buffer. Data stored in the Display Buffer is formatted prior to entry into the buffer.

9. ARITHMETIC UNIT - The ARITHMETIC UNIT board contains a number of different arithmetic units, some of which are internally cross-coupled and all of which are connected to the system "D" bus at their input and contribute to the "D" bus via the Bus Multiplexer at their output. The ARITHMETIC UNIT also includes the Input Buffer Memory and Control, the Vertical and Horizontal D/A Latches, and Index Registers for general control, as well as the Bus Multiplexer. These blocks will be described in the paragraphs that follow:

a. "R,r" Arithmetic Unit - This arithmetic unit contains two extensive registers, corresponding arithmetic logic units, and additional multiplexing and control. It is used, in conjunction with the "I,i" Arithmetic Unit to perform FFT data processing, as well as the bulk of display, averaging, and control processing. This arithmetic unit has direct access to the output of the Look-Up Tables, i.e., the "P" bus, and the output of the "I,i" Arithmetic Unit, as well as the system's common "D" bus.

b. "I,i" Arithmetic Unit - This arithmetic unit is structured identical to the "R,r" Arithmetic Unit and shares the bulk of system processing with that unit. Note that both these arithmetic units are controlled by a common instruction field; however, the resultant decoded instruction to these arithmetic units generally represents two different operations for the two units.

c. "A" Arithmetic Unit - This is an auxiliary arithmetic unit primarily intended for angle accumulation in the FFT algorithm but used in various portions of the program where its use is required.

d. Index Registers - A set of two independent index registers are available for program use as delay or time-out elements. Their carry outputs are capable of being sensed and are generally used in a conditional jump operation.

e. Vertical and Horizontal D/A Latches - Data that is ready for transfer to the Display Subsystem is entered into these latches directly from the outputs of the "R,r" and the "I,i" Arithmetic Units. Loading of these latches is, of course, controlled by the program and occurs only during the display portion of the program.

f. Input Buffer Memory and Control - Data from the A/D Converter, or data from an external source when selected, is entered into a 1024 word buffer memory. Writing into this memory occurs at the data sampling rate and is essentially independent of program control. However, reading of data from this memory is entirely under program control and must be distinct in time from the write operation. Consequently, writing into the memory will be inhibited during a read operation and will be executed immediately thereafter if a write request is present.

As shown on the block diagram, data read from this memory is one of the inputs to the Bus Multiplexer and appears on the "D" bus when selected by the program.

g. Bus Multiplexer - This multiplexer includes every major bus output from an arithmetic or memory unit, as well as front panel multiplexed bus, address-field literal data, and the Look-Up Table "P" bus output. The control of the Bus Multiplexer is derived from a separate field in the instruction word and, although not shown on the block diagram, may be overridden by external select commands.

h. Bus Multiplexer Decoder - Data appearing on the "D" bus also appears on the buffered "DX" bus at the J101 rear panel connector. However, only certain types of data are significant for an external device; consequently, it is necessary to provide a read strobe and an identification code on the bus itself to alert the external device to the type of data currently on the bus. Whenever the 444 provides output data, a restricted code is used to select one of the inputs to the multiplexer. Upon detection of this code, the Bus Multiplexer generates a $\overline{\text{DX READ}}$ strobe, nominally two microseconds in duration during which time data remains stable on the "DX" bus. The coded portion of the "DX" data may be examined during the time $\overline{\text{DX READ}}$ is asserted and the device may either reject or accept the current data frame depending on the detected code.

10. DISPLAY BOARD - The DISPLAY BOARD contains the Vertical and Horizontal Digital-to-Analog Converters and the corresponding low and high voltage Deflection Amplifiers, as well as Z-axis level translators, plot control circuits, coordinate rotation controls, and gain and offset controls.

SECTION VII

USER ADJUSTMENTS

7-1. Scope of This Section

This section of the instruction manual provides the user with the necessary information for adjusting certain system controls without the need to introduce special test equipment. Controls other than those provided for customer use will be included in this section for information only. These controls have been preset at the factory and should not be readjusted without prior consultation with Nicolet's Service Department.

7-2. Input Offset Adjustments

A. AC Coupling:

Set the following switches to their indicated positions:

TEST/AC/DC	to AC
VIEW	to TIME
ANNOTATION	to FULL
FREQ/ORDERS	to FREQ
HOLD/REL	to REL
INPUT SIGNAL	to none

The display should consist of a horizontal line aligned with the fifth vertical tic mark. If this line is not on the fifth tic mark, adjust potentiometer R1 (20,000 ohms) on the AD CONVERTER for proper alignment.

B. DC Coupling:

Set the TEST/AC/DC switch to DC. All other settings should remain as in paragraph A. above.

Set INPUT AMPLITUDE control to its maximum clockwise positions, i.e., 100 MV, and ground the INPUT SIGNAL BNC.

Again the display should consist of a single horizontal line at the fifth vertical tic mark. If this is not so, three controls may be adjusted for centering the line.

On the INPUT ATTENUATOR card adjust potentiometer R1 (1000 ohms) and R2 (20,000 ohms) for proper centering of the horizontal line.

If there is insufficient range in this adjustment, potentiometer R15 (20,000 ohms) on FILTER NO. 2 may be adjusted to complete the centering alignment.

7-3. Input Gain Adjustment

Set the following switches to their indicated positions:

TEST/AC/DC	to AC
INPUT AMPLITUDE	to 0 dB (COARSE and FINE)

Apply a sinusoidal INPUT SIGNAL at a frequency of one percent of selected FREQUENCY RANGE and at an amplitude of 280 MV peak to peak (100 MV RMS).

Set the VIEW switch to TIME and verify that the displayed signal is at the threshold of clipping at both top and bottom extremes. If not, adjust potentiometer R2 (2000 ohms) on the A/D Converter until this occurs. If slight clipping is not symmetrical, it may be necessary to readjust the AC offset control outlined in paragraph 7-2, A., above, and then repeat the gain adjustment. After symmetrical clipping is achieved, no further offset adjustment should be made, although exact centering may have been slightly affected in the gain adjustment procedure.

7-4. A/D Converter Adjustments

The following potentiometers on the A/D Converter are used to adjust the relative weights of A/D Converter bits. They are listed below for information only and should not be adjusted without prior consultation with Nicolet Scientific Corporation.

Control	Function
R3	Correct weight for 1/2 MSB
R4	1/4
R5	1/8
R6	1/16
R7	Correct weight for the sum of all succeeding lower bits, equal to 1/32 MSB.

7-5. Display Adjustments

Unless otherwise noted, all display adjustment controls are located on the Display Circuit board. (See Figure 7-1.) Extreme caution should be used when servicing the Model 444 with any of its side panels removed. Lethal voltages exist within this unit. The Display Circuit controls should always be adjusted through the holes provided on the protective plexiglass cover. Removal of this cover with power applied to the unit should be attempted by trained personnel only. All adjustments made by the user are to be made to achieve the optimum result based on the function of that control only. In general, optimum results are observed on a working display with the FULL ANNOTATION on.

1. FOCUS - This control is mounted in a small enclosure on the frame behind the Display Circuit board. This control is adjusted to achieve optimum definition of both horizontal and vertical lines on the display. The control will generally interact with the ASTIGMATISM control and should be adjusted under normal screen intensity setting.

2. INTENSITY - This control is located directly below the FOCUS control. The adjustment may be made to suit the viewer for ambient lighting conditions; however, excessive brightness makes FOCUS adjustment more difficult and may shorten the life of the CRT.

3. R13, ASTIGMATISM - Adjust this control for equal focus of horizontal and vertical lines. Readjust FOCUS if necessary.

4. R14, PATTERN CORRECTION - Adjust this control for minimum bowing of the vertical graticule lines. Check corners

of the graticule for optimum alignment with horizontal graticule lines. This control will generally interact with the ASTIGMATISM control.

5. R4, VERT ROTATE and R10 HORIZ ROTATE - These controls are adjusted to achieve a graticule whose vertical and horizontal lines are perpendicular to each other and parallel to the vertical and horizontal edges of the CRT, respectively. Both controls will generally have to be adjusted simultaneously.

6. R7, VERT HF ADJUST and R1, HORIZ HF ADJUST - These controls affect the high frequency compensation of the two deflection amplifiers. Their effect can best be observed at the graticule corners. Adjust these controls so that at the corners of the graticule the horizontal and vertical lines meet with minimum change in slope and intensity, and with minimum overshoot.

7. R8, Y OFFSET and R2, X OFFSET - These controls may be used to obtain a pattern optimally positioned vertically and horizontally on the CRT. Note that if the VERT. OFFSET or HORIZ. OFFSET controls are subsequently adjusted for minimum offset on Y OUT or X OUT signals, the Y OFFSET or X OFFSET controls may require readjustment for optimum centering on the CRT.

8. R3, HORIZ SPAN; R9 VERT SPAN - These controls are used to control the gain in the horizontal and vertical axis.

9. R12 VERT OFFSET; R6 HORIZ OFFSET - These controls are normally factory preset so that an all zero digital word into the D/A Converters will produce an analog output of zero volts at the X-Y plotter outputs. However, if for any reason the user wishes to readjust these controls to suit his needs, he may do so. It will then be necessary to readjust the X OFFSET or Y OFFSET control for CRT centering since the offset added by the first adjustment is also in the main signal path.

10. R5, X CRT ZERO; R11, Y CRT ZERO - These controls are normally factory preset so that the X and Y outputs to the external display will be at a zero volt reference. However, if for any reason, the user wishes to readjust these controls to suit his needs, he may do so by displaying the outputs on his X-Y oscilloscope and adjusting these controls for optimum centering.

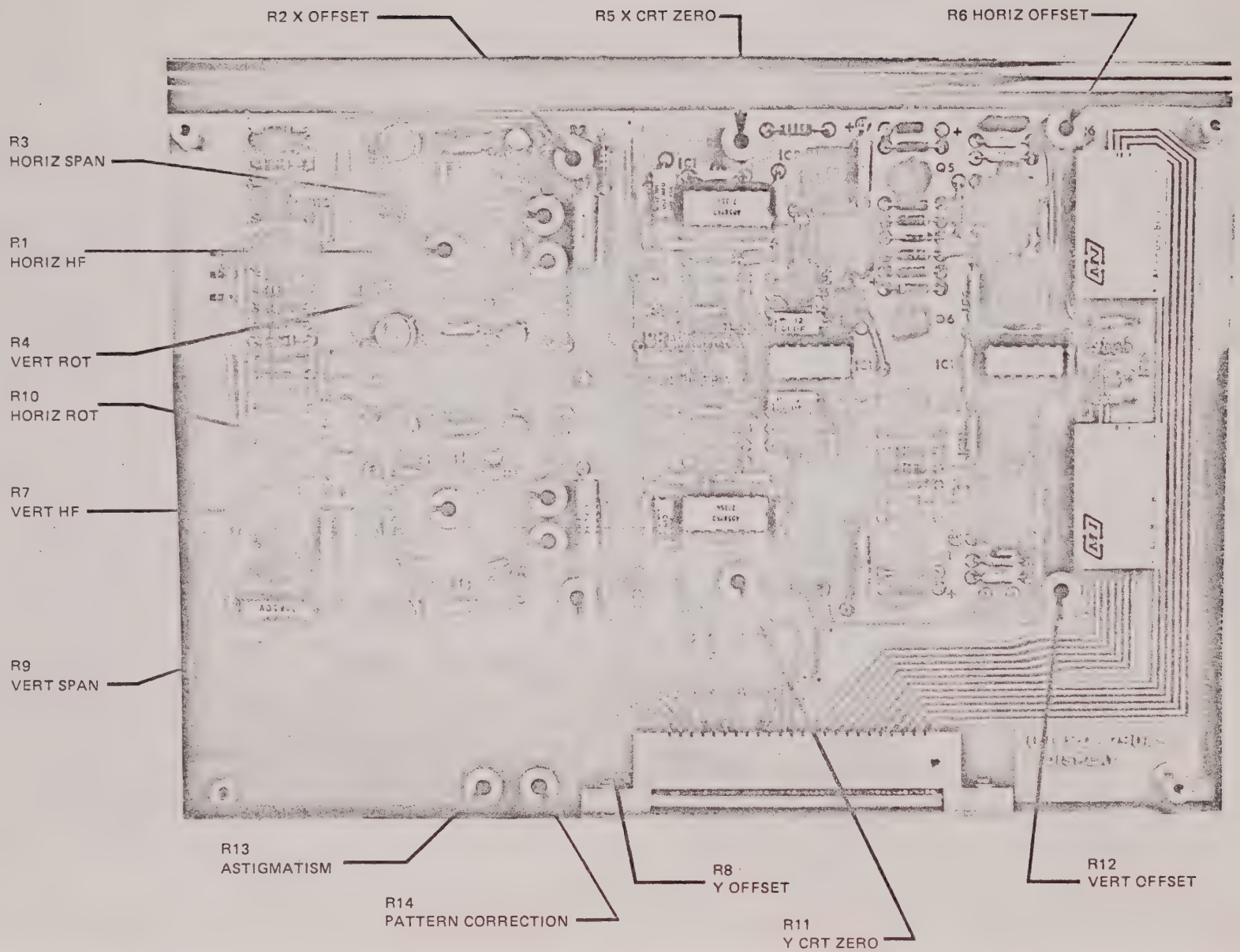


FIGURE 7-1. DISPLAY BOARD ADJUSTMENT LOCATIONS

7-6. Power Supply

A. Description

This power supply convertor employs the switching type inductor storage design. The unit is capable of delivering a regulated +5 volt output and unregulated +20, -20, +40, -40, and +225 volt outputs. The regulated +5 volt supply is adjustable between 4.50 volt to 6.25 volt at the output connector. In addition, the convertor has an inherent self-protecting power-limiting capability.

The unregulated outputs are regulated by the regulator board to provide regulated +15, -15, +30, -30 and +175 volt outputs. In addition, this supply includes a high voltage convertor section which generates the +1500, -1500, and 6.3 volt output for the cathode ray tube power requirements.

All the voltages have a common floating ground at the output of the main power convertor. Table 7-1 summarizes the output voltages and maximum currents from the supply.

Table 7-1. Power Supply Outputs

Voltage (Volts DC)	Maximum Current (Ampere DC)
+5.2	14
+15	1
-15	1
+30	0.1
-30	0.1
+175	0.02
+1500	20 μa
-1500	20 μa
-900	20 μa
6.5 (AC)	0.3 (AC rms)
+38 unregulated	

B. Convertor Block Diagram

Figure 7-2 is a simplified block diagram of the main power convertor. It consists of five major elements.

a. Line EMI Filter, Rectifier and Filter
b. Oscillator
c. Drivers and Switches
d. Transformers, Rectifier, and Filters
e. Feedback Amplifier and Isolator.

C. Theory of Operation

Line voltage is passed through an Electro-Magnetic Interference filter. This is to prevent high frequency noise generated in the convertor from being fed back into the line, and line noises from entering the system through the power supply.

The AC line voltage is then fed to the rectifier circuits. This circuit consists of a voltage doubler and filter for 110V AC input or a full wave rectifier and filter for 220V AC input. This rectified voltage (V+) is the main operating voltage for the convertor, and is between 250V DC and 350V DC.

During initial start-up condition, the oscillator obtains its operation voltage (B+) from V+ through a 5 volt series regulator. Once normal operating conditions are established the oscillator utilizes one of the main transformer outputs. The start-up operating voltage of B+ is 5 volts and the normal operating voltage of B+ is between 8 to 15 volts.

At 5 volts, the oscillator will operate as bistable oscillator with fixed frequency and duty cycle. At voltages above 5 volts, the oscillator will operate as voltage controlled oscillator with fixed "on" cycle. The controlling voltage is the output of the feedback error amplifier. The output of the oscillator is the switching pre-driver for the driver stages.

There are two identical drivers, each driving an independent switching transistor in series with the transformer. During "on" periods, the transformer will have the characteristics of a pure inductor because all the secondary rectifier diodes are reverse biased. The electrical energy is now stored in the transformer as magnetic energy. As soon as the switch is off, the current feeding through the transformer is temporarily cut off.

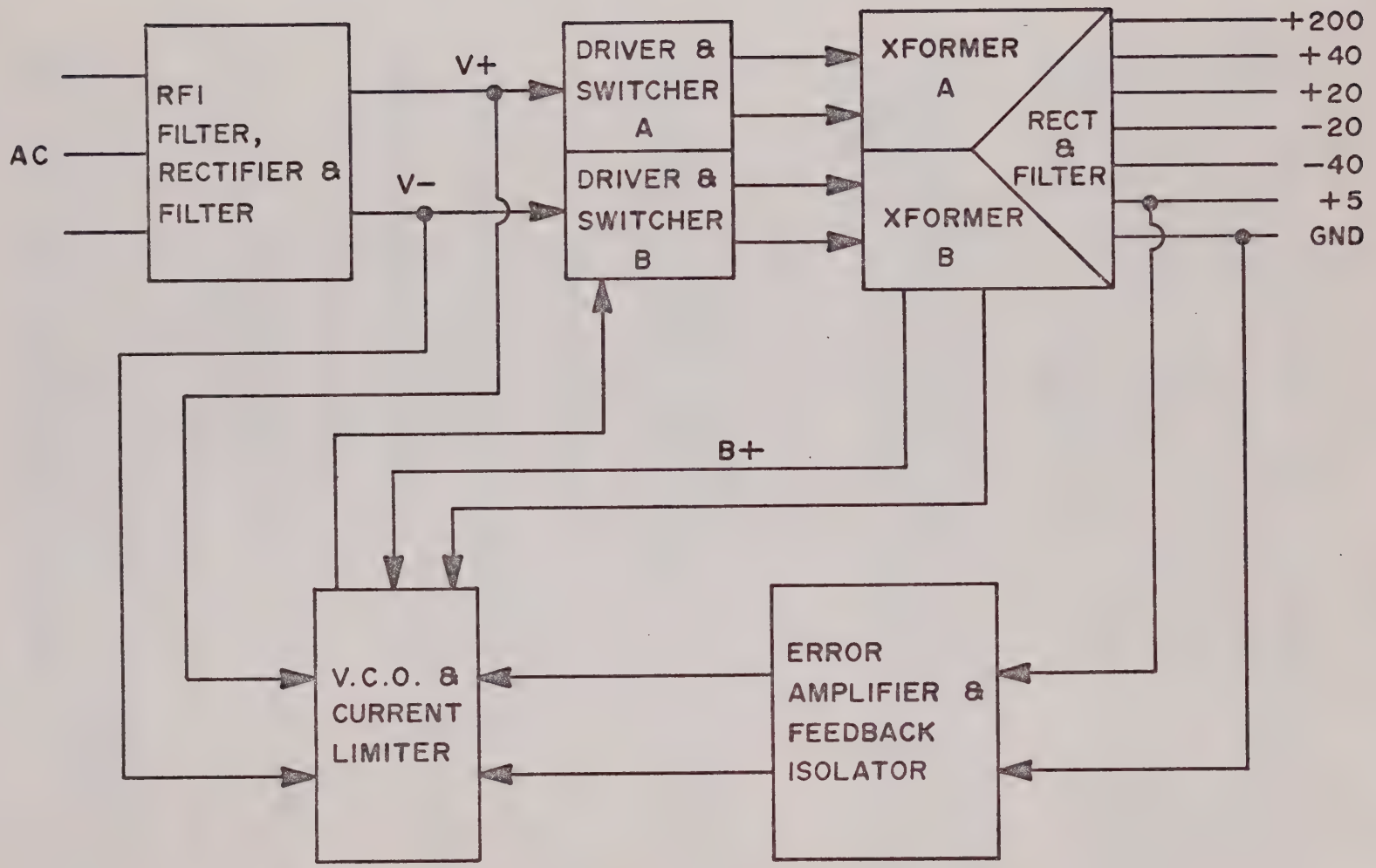


Figure 7-2. Block Diagram for the Model 444 Power Supply

The natural behavior of an electromagnetic circuit is to oppose any sudden change of current in the inductor by trying to maintain an equal but opposite magnetic field. This opposing magnetic field will generate reverse potentials on all the electrical windings of the transformer until the rectifier diodes are forward biased. At that instance, the magnetic energy is transformed into electrical energy, and the secondary circuits will then filter and store the energy to provide a DC output. One of these secondary outputs is the oscillator operating voltage as mentioned earlier.

The controlling feedback circuit operates from the +20 volt output. This circuit will compare the +5 volt output to an adjustable reference voltage, amplify the error and generate a DC level. This level is the controlling voltage to the voltage-controlled oscillator. Isolation is accomplished via an optoisolator.

D. Troubleshooting Procedure

It is recommended that the supply be serviced only by trained personnel. Before attempting to troubleshoot this power supply, confirm that the fault is with the power supply and not with the associated circuits.

Safety Precautions

1. Always use an isolated, variable AC power source for the power supply during troubleshooting.

2. Always remove input power before adding on or removing components from the power supply.

Troubleshooting

Note the mode of failures on the power supply and follow the procedure indicated.

1. All output voltages low (O.V.). See Fig. 7-3.

2. Has +5 volt output, but one or more of the other voltages are low or missing; +5 volt output normal, but one or more of the other outputs are either high or low. This does not include high voltage CRT outputs.

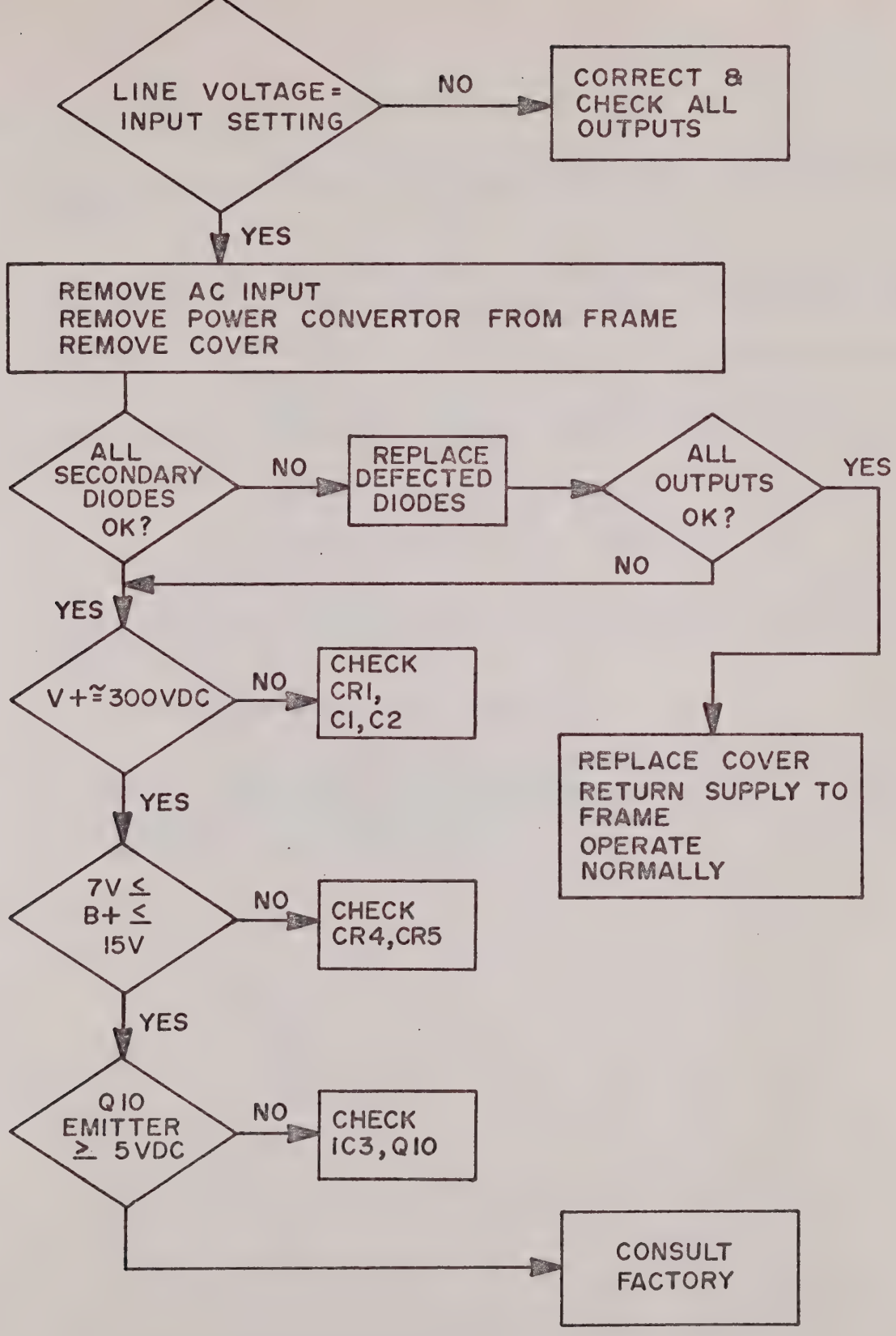


Figure 7-3. All Output Voltages Low

a. Check +15 and -15 output first.

b. If +15 and -15 are normal, then check +30 and -30 outputs. Replace regulator related to the abnormal outputs.

For +175 volt output, if output is high, check the series transistor. If output is low, check the feedback transistor.

WARNING: Do not attempt to troubleshoot high voltage convertor.

3. High ripple on one or more of the outputs. Replace 6.8 uf capacitor from the abnormal output regulator.

4. AC main fuse blown. See Figure 7-4.

5. AC supply fuse blown. See Figure 7-5.

6. Repeated thermal shutdown occurred. Check fan. If fan is running and there is no obstruction to air flow, consult factory.

E. Power Supply Adjustments

There are five adjustments available to the user for setting the systems' operating voltages. Table 7-2 lists the location of the controls, the recommended monitoring points and the correct voltage settings.

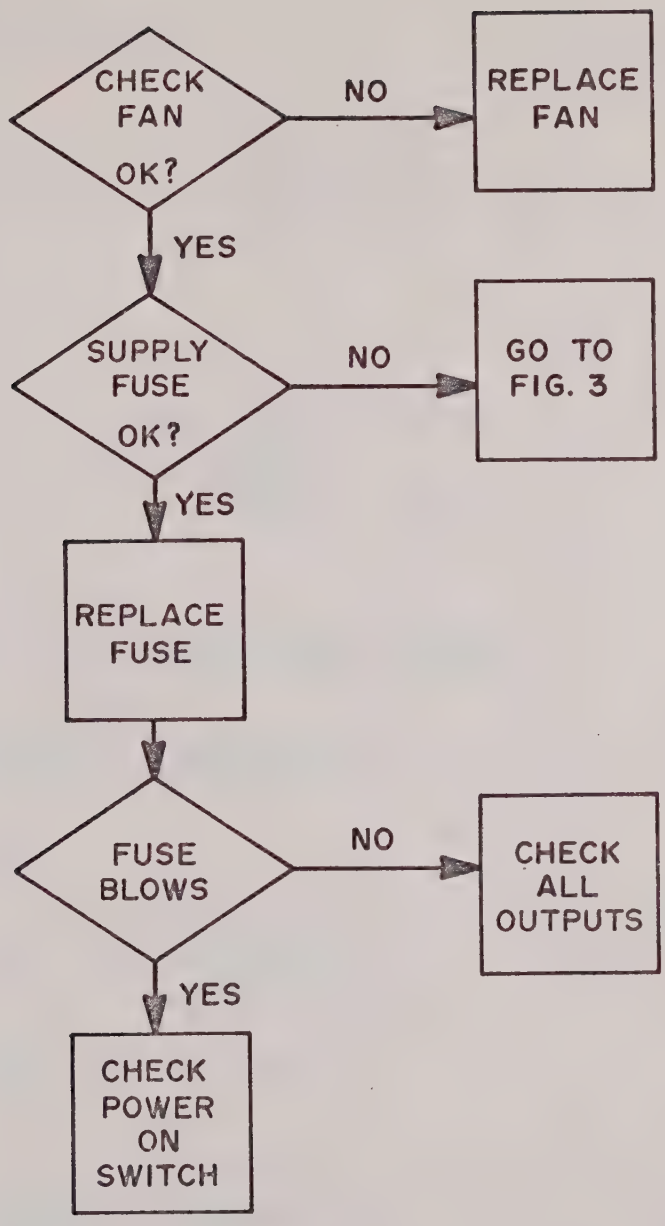


Figure 7-4. AC Main Fuse Blown

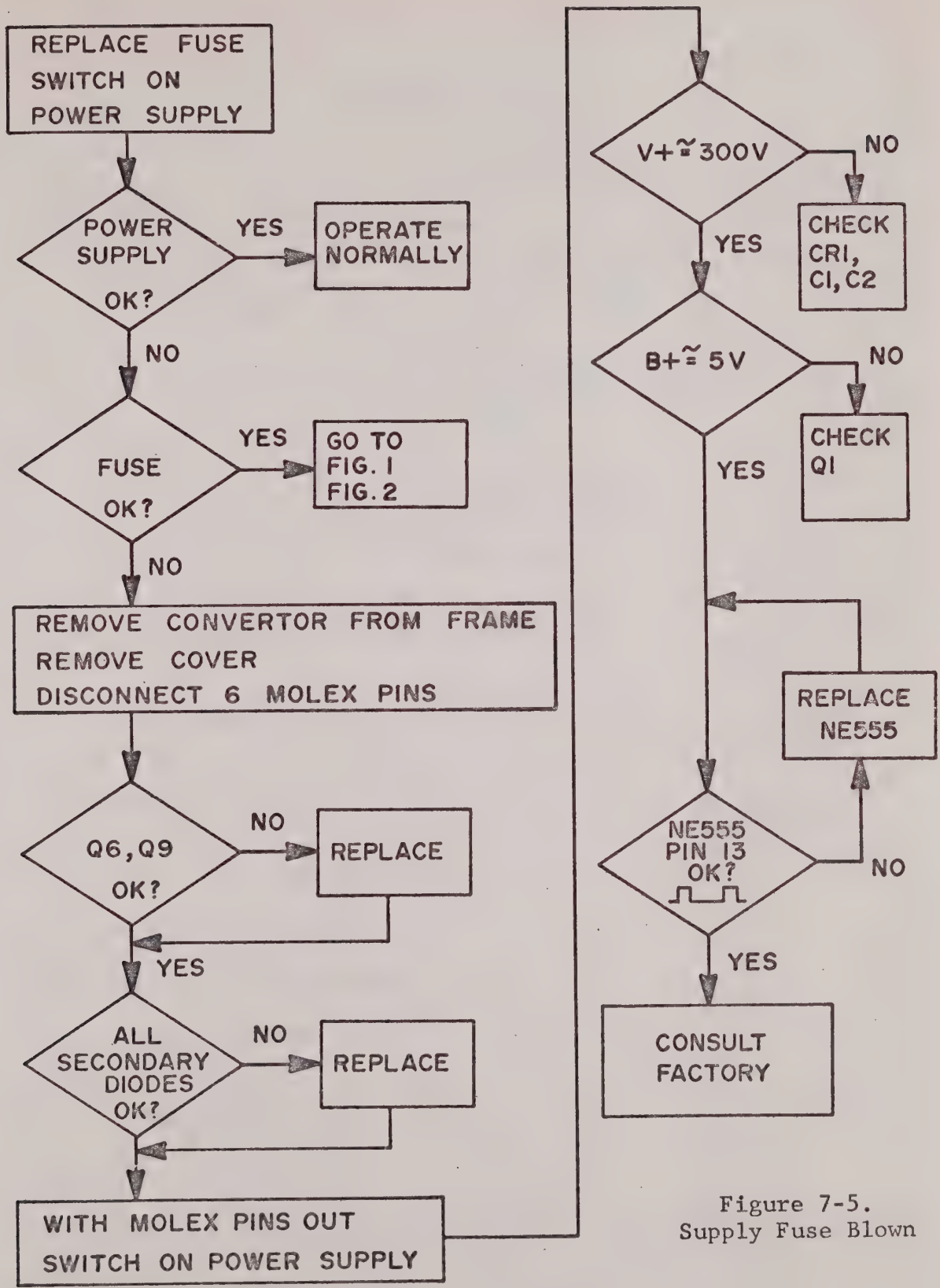


Figure 7-5.
Supply Fuse Blown

Table 7-2
Voltage Adjustments

Voltage/ Control	Adjustment Location	Monitoring Points	Voltage Settings
+5 volts	Rear Panel - Lower Left Corner	a. Program Control Board - Input side of fuse	5.0 volts
		b. Arithmetic Unit Input side of fuse	5.1 volts
		c. Rear Panel - Monitor Point	5.2 volts
+15 volts	See Fig. 7-6	See Fig. 7-1	+15 volts ±100 mv
+30 volts	See Fig. 7-6	See Fig. 7-1	+30 volts ±100 mv
-15 volts	See Fig. 7-6	See Fig. 7-1	-15 volts ±100 mv
-30 volts	See Fig. 7-6	See Fig. 7-1	-30 volts ±100 mv
+175 volts	Not Adjustable		
+1500 volts	Not Adjustable		
-1500 volts	Not Adjustable		
6.3 volts	Not Adjustable		
FOCUS	Refer to Section 7-5		
INTENSITY	Refer to Section 7-5		

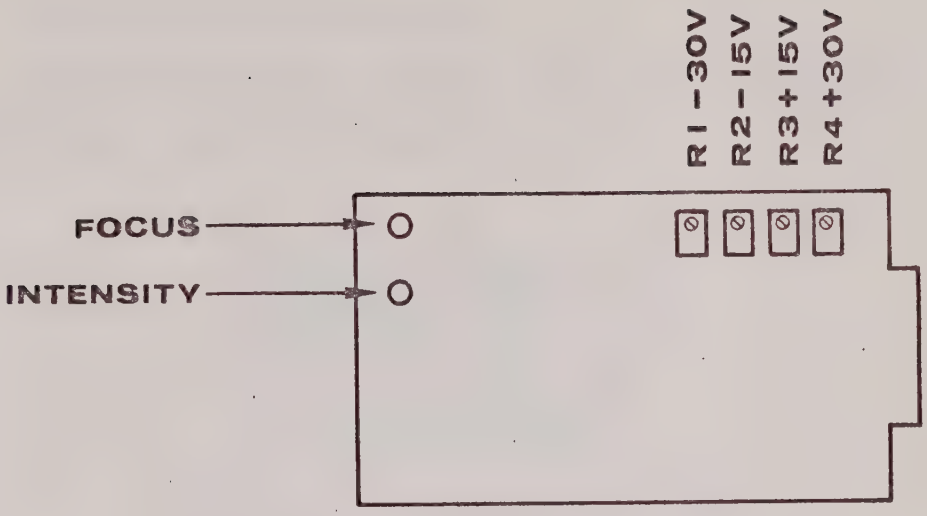


Figure 7-6. ±15, ±30 Volt Adjustment Location

SECTION VIII

–2 EXPANSION PLUG-IN OPTION

8-1. Frequency Expansion Option

This section describes the operating controls, theory of operation, and checkout procedure for the -2 EXPANSION PLUG-IN Option, shown in Figure 8-1, below.

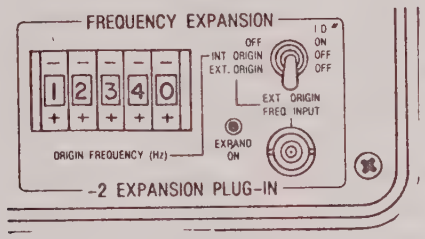


FIGURE 8-1. -2 EXPANSION PLUG-IN

8-2. -2 EXPANSION PLUG-IN Front Panel Controls

A. OFF/INT. ORIGIN/EXT. ORIGIN

1. OFF - This position of the switch bypasses the FREQUENCY EXPANSION function and permits normal operation. In this mode the FREQUENCY RANGE of the analyzer extends from 0 Hz to the maximum frequency indicated by the FREQUENCY RANGE switch.

2. INT. ORIGIN - This switch position enables the FREQUENCY EXPANSION function. In this mode of operation, the frequency axis of the display is expanded to cover a 100-Hz range starting at the frequency set on the ORIGIN FREQUENCY (Hz) digital switch.

Note

100 Hz is the standard filter bandwidth supplied with the -2 EXPANSION PLUG-IN Option. Bandwidths of 10, 20, 50, 500, 1,000, 2,000, 10,000 and 20,000 Hz are available as options.

8-1. Overall View

The UA-444 is comprised of four major blocks of circuitry (see Figure 1). The main purpose of the Option 05 is to confirm that a majority of the Digital Signal Processor is operational. For the Option to work, the Display Circuits and CRT must be operational so that when malfunctions are found, they can be presented on the CRT screen. For this reason, there exists the capability within the Option to confirm that the Display Circuits and CRT are functional. Referring back to Figure 1, one can see that two major blocks have not been tested by the Option 05. They are the Front End Section and Power Supply. These two blocks must be serviced by conventional means. There exists an indication of power supply operation on the front panel, namely, the POWER ON lamp. There also exists an indication of front end operation, namely, the test mode of the AC, DC TEST switch. So one can see that within the 444 there are several built-in aids useful in servicing the instrument.

8-2. Processor Section

Referring to Figure 2, one can see that the processor section is made up of nine major blocks. Although the Option 05 exercises just over two of these major blocks, the circuits tested comprise approximately 375 of the 525 IC's within the unit or 70 percent of the processor section. Also, in order for Option 05 to work successfully, the "Decoder Proms" and the "Program Counter" must also work, accounting for an additional five percent of the processor unit. The "Misc Instruction Decoder" and the "Program Memory" is not tested by the Option 05 but going on past experience, they have accounted for a very small percentage of the UA-444's failure.

8-3. Using the Option 05

All the circuits tested by the Option 05 can be divided into two major categories. The first being the hardwired logic and the second being the random access memories, (RAMS). Since testing of the random access memories is a comparatively long test with respect to the hardwired logic, there is provision via a front panel switch to select whether or not the RAMS are tested in addition to the hardwired logic. To enable the Option 05, proceed as follows:

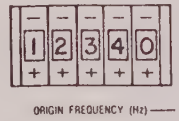
The ORIGIN FREQUENCY (Hz) may be varied from 100 Hz (or the optional filter bandwidth) to 99,900 Hz. Although operation is possible with the origin frequency below 100 Hz, spurious signals may be generated which will be visible on the spectrum display. If a spectrum display below 100 Hz is desired, it is advisable to use the standard lowpass ranges of the 444 Spectrum Analyzer.

3. EXT. ORIGIN - In this position operation of the frequency expansion function is similar to that described in paragraph 2, above, except that the ORIGIN FREQUENCY is determined by an external frequency reference source, applied to the EXT. ORIGIN FREQ INPUT connector.

B. EXTernal ORIGIN FREQuency INPUT

In the EXT. ORIGIN mode a 1-volt RMS sinusoidal signal applied to this connector will determine the origin frequency. The frequency of the signal applied to this connector is 100 kHz plus the desired origin frequency. The origin frequency is subject to the same limitations outlined in paragraph A-2, above.

C. ORIGIN FREQUENCY (Hz)



The ORIGIN FREQUENCY (Hz) digital switch is used to select the location of the lower frequency edge of the 100 Hz filter bandwidth when the INT. ORIGIN mode of operation is selected. This digital switch may be adjusted in 10-Hz steps from 00000 to 99990 Hz although only the range from 00100 to 99900 should be used.

D. EXPAND ON Indicator

This light emitting diode is illuminated whenever the Frequency Expansion function is ON.

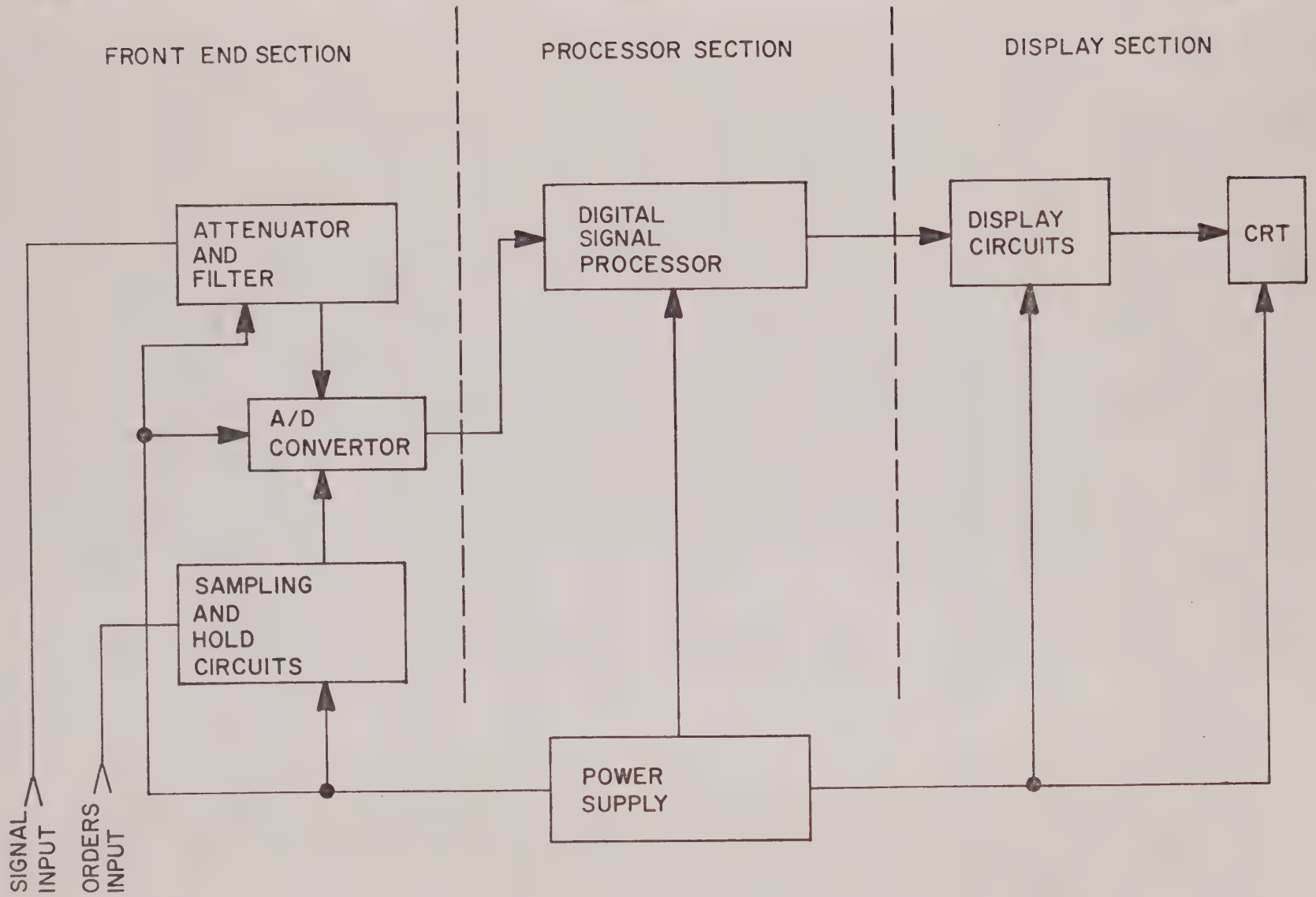


Figure 1. Overall Block Diagram

8-3. -2 EXPANSION PLUG-IN Checkout

This procedure requires the use of a sinusoidal signal generator (audio oscillator).

A. Set front panel as shown in Table 4-1 with the following exceptions:

1. TEST/AC/DC in AC
2. FREQUENCY RANGE in 500 Hz
3. FREQUENCY EXPANSION/OFF/INT. ORIGIN EXT. ORIGIN in OFF
4. CURSOR: FREQ/OFF

B. Set ANNOTATION switch on rear panel to the FULL position.

C. Apply a 100 MV RMS, 250* Hz sinusoidal signal to the INPUT SIGNAL connector on the front panel. (See page 8-3a.)

D. Set the ORIGIN FREQUENCY (Hz) digital switch to 00200 Hz.

E. Observe that the display is a single spectral line centered on the frequency axis.

F. Place the FREQUENCY EXPANSION/OFF/INT. ORIGIN/EXT. ORIGIN in the INT. ORIGIN position.

G. Observe the display remains as describe in paragraph E, above, except that the frequency range annotation now reads 100.

Note

If optional filter bandwidth ranges have been installed, then frequency range annotation field should match the range installed.

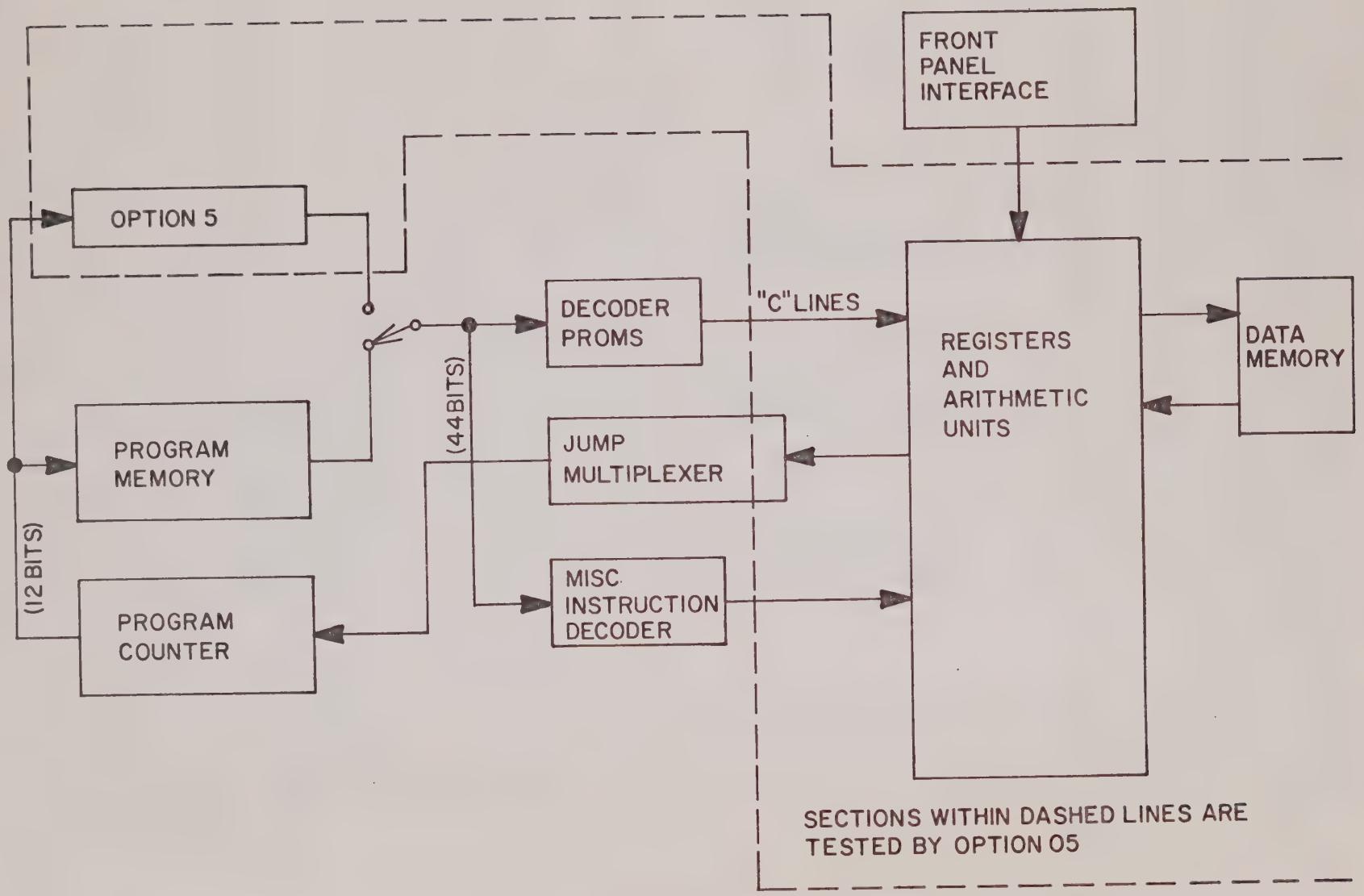


Figure 2. Processor Block Diagram

H. Change the setting of the ORIGIN FREQUENCY (Hz) digital switch to 00160*. Observe that the display remains the same except that the spectral line (corresponding to the input signal frequency) is now located at the ninth tic mark on the horizontal axis.

*For Expansion Ranges other then 100 Hz, use the following settings in place of those given above:

Optional Filter Bandwidth	Line A2	C	D	H
10	500	205	00200	00200
20	500	225	00220	00210
50	500	245	00220	00200
100 STD	500	250	00200	00160
500	2,000	1,000	00750	00550
1,000	5,000	2,500	02000	01600
2,000	10,000	5,000	04000	03200
10,000	40,000	20,000	15000	11000
20,000	100,000	50,000	40000	32000

NOTE: For the 50 Hz filter, the signal is not centered in display for Step E.

For the 20 Hz filter, the signal is not centered in display Step E. In Step G the the display is at 25 percent of the window. For step H it will be shifted to 75 percent.

For the 10 Hz filter, the signal is not centered in display Step E. For Step H do not change ORIGIN setting. Instead change input frequency to 209 Hz. Note signal appears near ninth tic.

a. Depress the CONT A switch on the front panel and hold the button.

b. Depress the START A switch on the front panel without releasing the CONT A switch.

c. Continue to hold both switches depressed for about three seconds or until the CRT display disappears.

The position of the CURSOR switch will determine whether or not the RAMS are tested. When the cursor is off, the RAMS are not tested. When the cursor is either "Single" or "Harmonic" the RAMS are tested. The total time for the test is as follows:

a. Hardwired Logic Alone - about one second each successful pass through the Option 05 routine. The averager IN PROCESS light will flash on every alternate pass through the routine.

b. Hardwired Logic and RAMS - about one minute for each successful pass through the Option 05 routine. The "tree" (amplitude level lights on lower front panel) will be illuminated for about 50 percent of the time for each pass and the averager IN PROCESS light will flash at a rapid rate.

In order to test the CRT circuits, merely depress the STOP A button while the Option 05 is running. Three rows of ones and zeros should appear on the CRT screen, confirming that if an error is found by the Option 05, it can be displayed on the CRT. To clear the CRT display, merely depress the START A button to proceed with the Option 05 routine. Note: it is possible to have an error displayed on the CRT the first time the Option 05 is enabled. If this happens, merely depress the START A button again to restart the Option 05.

When the Option 05 is running, the averager IN PROCESS light will flash at either of the two rates mentioned above; but when an error is detected, the light will remain in a steady state (either always on or always off) and the CRT will display three rows of ones and zeros. This is not true when the Option 05 is running and the STOP A button is pushed. In this case, the CRT will display the three rows of ones and zeros, but the averager IN PROCESS light will continue to flash indicating the Option 05 is still running. Therefore, it is obvious that once the CRT circuits are confirmed to be working by depressing the STOP A button, the START A button must be depressed to clear the

8-4. -2 EXPANSION PLUG-IN Block Diagram Description

This section presents a block diagram description of the -2 EXPANSION PLUG-IN FREQUENCY EXPANSION circuitry.

When either of the frequency expansion modes (INT. or EXT. ORIGIN) is selected, the input signal is applied through a buffer amplifier to a double balanced mixer (DBM). The origin frequency signal, either from the internal synthesizer or from the external origin frequency source is also applied to the DBM.

The output of the DBM is amplified and drives a lower sideband crystal filter. This filter limits the bandwidth of the input signal to 100 Hz (optional bandwidths of 50, 500, 1000, and 2000 Hz are available). The origin frequency control allows the lower frequency edge of the 100-Hz bandwidth to be moved from 100 Hz to 99900 Hz.

The output of the crystal filter is buffered and is applied to another DBM. In this mixer the filter output is shifted down in frequency until the origin of the 100-Hz bandwidth is 10 Hz. This output is applied directly to the input anti-aliasing filters of the 444 Spectrum Analyzer.

8-5. Changing Filter Bandwidths in the -2 EXPANSION PLUG-IN

The standard filter bandwidth for the -2 EXPANSION PLUG-IN is 100 Hz. Optional filters of 50, 500, 1000, and 2000 Hz are available and may be readily interchanged. The following procedure outlines the steps necessary to interchange Down Converter and Filter Board subassemblies to effect changes in filter bandwidth:

A. Turn OFF the power switch on the Model 444.

B. Unlock and remove the lower front panel drawer. This drawer is connected to the mainframe by a folding cable assembly. Do not remove these cables.

C. Locate the Down Converter and Filter Board Assembly. It is situated in the extreme right-hand position within the drawer directly behind the HOLD/REL pushbutton.

display and allow any error found by the Option 05 to be displayed. The Option 05 will continue running indefinitely unless it finds an error, at which point it will stop and display the error. Once an error has been detected, it is advisable to record the error on a piece of paper and then depress the START A button causing the Option 05 to begin again. Depending on whether or not the same error, if any, is again detected by the Option 05, you will have an idea if the failure is intermittent or permanent. To return the analyzer to its normal mode of operation, simply depress the RESET button (on the rear panel).

8-4. Locating IC's to be Replaced

All the IC's listed in this code book are located on two of the three main processor boards. Namely, the Arithmetic Unit (AU) and Program Control (PC) boards. To gain access to these boards, proceed as follows.

a. Shut off power.

b. Remove right-hand side dust cover.

c. Unclip the nylon rod from the outside board.

d. Unscrew the two screws located in the upper corners of the board.

e. Hinge down the outside board. Be careful to use the nylon rod to act as a support when the board is down.

Now the two boards that are exposed are the AU board (board hinged down) and the PC board (board still in a vertical position). You will note that both boards have IC's on the same grid coordinate system except that the AU board has provision for 24 pin IC's at the edge of the board, labeled IC1 through IC12. The remaining IC's are a Row/Column grid. Therefore, to locate an IC such as AU-C17, proceed as follows:

a. Locate the "C" row of the AU board (stencilled along the width of the board).

b. Locate the "17" column of the AU board (stencilled along the length of the board).

D. Carefully remove the Down Converter and Filter Board from its mounting socket. Disconnect the coaxial cable running between the Down Converter and Filter Board and the Up Cconverter Board.

E. Insert the replacement Down Converter and Filter Board into the proper socket in the drawer assembly. Reconnect the coaxial cable to the Up Converter Board.

F. Check that all boards and connectors are seated securely within the drawer.

G. Replace the drawer assembly into the Model 444 mainframe and secure the drawer lock. This completes the procedure.

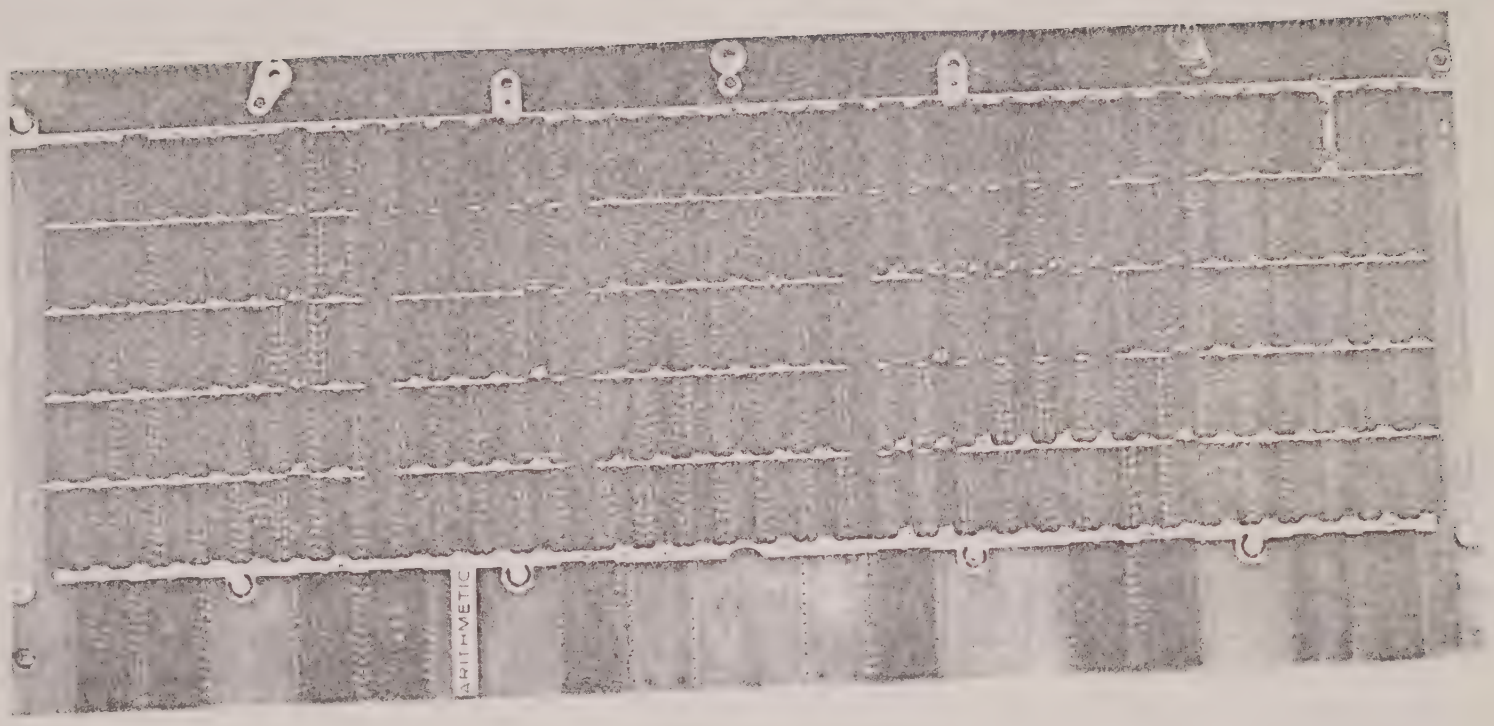


Figure 3. Typical IC Layout

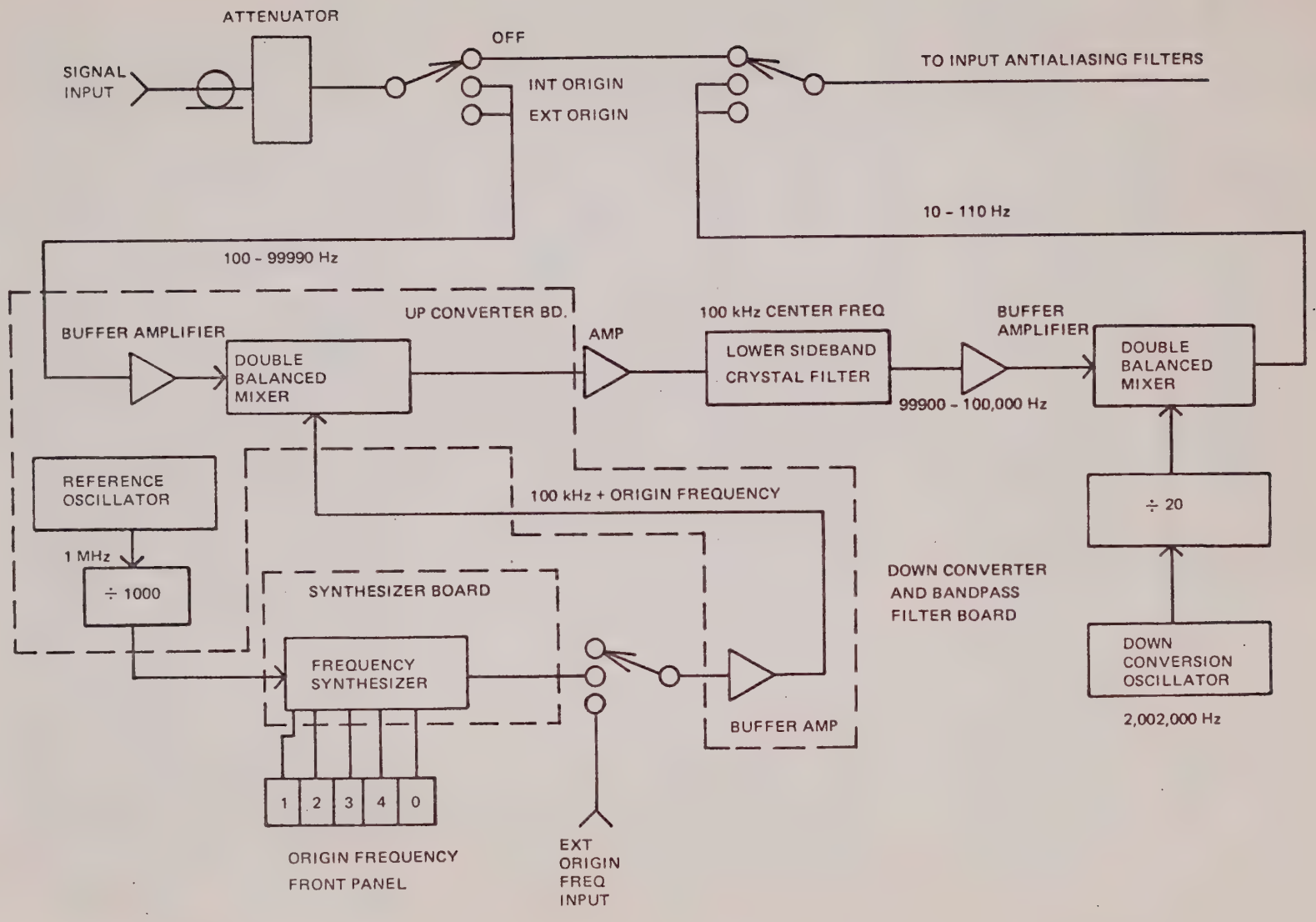


FIGURE 8-4. BLOCK DIAGRAM, -2 EXPANSION PLUG-IN

c. The IC located at the intersection of the "C" row and "17" column is the IC desired.

d. Using the IC extractor tool supplied, carefully remove the IC and replace.

On the AU board the markings for IC1 through IC12 are not clearly visible (almost covered by the IC itself). To locate one of these, simply start counting from the front of the unit. Therefore IC1 would be the 24 pin IC closest to the front of the unit and IC12 would be the IC closest to the rear of the unit.

8-5. Reading the Error Code

When an error is detected by the Option 05, three lines of ones and zeros will appear on the CRT screen such as shown in Figure 4. You can see that the top two lines contain twenty characters each and the third line contains twelve characters with several blanks. The twenty characters of the top two lines are numbered D0 through D19. (D0 is the left-hand character.) The third line is an address to be read in octal format. (See Figure 4.) In most but not all cases, the top line indicates the correct answer for the particular test in process and the second line indicates the actual answer received. In the example shown in Figure 4, an error occurred at address 0172 in bit positions D0, D1, and D2, since those are the only three bits that differ between the top two lines.

8-6. Reading the Code Book

The code book is divided into three columns. The first column is the error address. The second column indicates which bit positions (D0 through D19) have failed. Some failures do not require noting which bits are in error and for these situations Column 2 is left blank and the top two CRT lines can be ignored. The third column contains a list of the probable IC's that can cause the error. In the example shown in Figure 4, the error occurred at address 0172. Looking down the first column of the code book until address 0172, we see that address 0172 appears five times. What differs between these five errors is Column 2. Referring back to Figure 4 we see that the top two lines differ from each other in bit positions D0, D1, and D2. Returning back to the code book, it should be obvious that the error of interest could be the first one since the second

```
D - 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

    0 1 0 1 1 0 0 1 0 1 0  1  1  1  1  0  0  1  1  0

    1 0 1 1 1 0 0 1 0 1 0  1  1  1  1  0  0  1  1  0

          0     0 0 1     1  1  1        0  1  0

ADDRESS = 0       1           7              2
```

Octal Format for Third Line

0 0 0 = 0

0 0 1 = 1

0 1 0 = 2

0 1 1 = 3

1 0 0 = 4

1 0 1 = 5

1 1 0 = 6

1 1 1 = 7

Figure 4. Typical 05 CRT Pattern

Nicolet Scientific Corporation warrants each instrument manufactured by it to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, normal service charges will prevail. In this case, an estimate will be submitted before the work is started. Warranty returns must first be authorized by Nicolet Scientific Corporation.

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Nicolet Scientific Corporation reserves the right to make changes in the design of its instruments without incurring any obligation to make the same changes on equipment previously purchased.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If the instrument is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number, serial number, and purchase order number when referring to this instrument for any reason.

SHIPPING

If the unit fails to operate or any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty,

and include the model number and serial number of the equipment. On receipt of this information, we will give you service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid to Nicolet Scientific Corporation. If requested, an estimate of the charges will be made before the work begins, provided the instrument is not covered by the warranty.

3. If the instrument is to be shipped, it is imperative that it be properly packaged. Where possible, use the specially designed packaging material in which the unit was delivered.

This warranty is expressly in lieu of all other obligations or liabilities on the part of Nicolet Scientific Corporation, which neither assumes nor authorizes any person to assume for it any other liability in connection with the sale of its instruments.